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DAIRY SCIENCE

DAIRY SCIENCE

ITS PRINCIPLES AND PRACTICE

S/c

SECOND EDITION

by

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Edited by

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PREFACE

IT HAS BEEN THE AIM OF THE AUTHOR TO PRESENT IN THIS BOOK A COMPREHENSIVE treatment of the field of dairy husbandry. Although the book is designed primarily for use as a text for college students of dairy production, its usefulness is not limited to that field. Matters of general interest and concern as they relate to dairy husbandry are dealt with in a manner deemed appropriate for general agricultural students as well. The book, therefore, is intended to furnish the material essential in each of two college courses—the introductory course in dairying usually offered to all agriculture college students, and the course in dairy cattle management or milk production. Because of this, the subject matter is dealt with in two ways.

The material other than that dealing with specific production problems is of a general nature. Only such information is presented as it is thought essential for the student to gain a concept of the entire dairy industry, its scope, its problems, and a knowledge of the general characteristics of milk and its products. In presenting this material only authoritative established facts are given, and references to specific experimental works are omitted. For the convenience of those seeking additional information, however, reference reading lists for each chapter are given in the Appendix. Likewise lists of questions concerning the essential facts and principles found in each chapter have been prepared for teacher and pupil use and are presented in the Appendix. Constant reference should be made to them.

The problems pertaining to production are dealt with more exhaustively. It has been the object to present the latest and the most authoritative information available on these problems in this part of the book. Results of experiments are frequently given and matters of a controversial nature are discussed, great care being taken to present valid evidence on all aspects of the issues raised. The most important literature dealing with these problems is cited in order that the student desiring to study more exhaustively may do so.

The subject matter is presented not necessarily in the order in which it should be taught but rather in the order of logical development from the author's point of view. First is a treatment of the historical and economic aspects which encompass and integrate the entire dairy industry. Following this broad general consideration is the author's treatment of specific problems; first, of those related to production, and second of those having to do with the handling, care, and processing of milk and other dairy products.

In preparing this book, it is also hoped that the wide scope of the ma-

terial content therein will serve as an aid to the teaching of vocational agriculture in public high schools, particularly as a reference book. For the same reason, and because of the fact that the practical problems confronting the dairy farmers have been extensively treated, it is hoped that the book will be of value to progressive dairymen.

Acknowledgment is gratefully made to Dr. H. C. Trelogan, Assistant to the Administrator, Agricultural Research Administration, U. S. Dept. of Agr., for contributing Chapters 2 to 9, dealing with the economic phases of dairying; to Dr. E. O. Herreid, a former colleague, now of the University of Illinois, for contributing the chapter of Microbiology; to the officers of the various breed associations for furnishing helpful information; to members of the dairy staff of the University of Minnesota, especially Dr. T. W. Gullickson, and to others for assistance and helpful criticism.

The 1950 edition of *Dairy Science* brings all charts and graphs up to date, presents the newest procedures and methods relating to dairying, and gives references to recent journals and publications.

W. E. PETERSEN

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DAIRY SCIENCE

Chapter I

THE HISTORY OF DAIRYING

It is not known just when the cow first became the servant of man nor when milk and milk products were first used. This, undoubtedly, came to pass long before man had advanced far enough to leave permanent records. The historians, archaeologists, and paleontologists, however, have found evidences of various kinds indicating that the domestication of the cow and the use of her product goes back to the time of the early development of the human race. Before her domestication the cow was probably hunted by the savage and barbarian early man.

The evidence reveals that the extent to which cattle were used and the kind of uses made of them vary greatly with the different peoples and cultures. It is known that the cow has served man through the ages as a beast of burden, as a source of food, as an object of worship, as the source of sacrificial offering, and as an object of mythology. Milk and milk products have been used for food, for sacrificial offerings, for cosmetics, and for medicants. A general knowledge of the early uses of the cow and her product, together with information regarding the early practices, will furnish a background for the study of the development of dairying. In addition, these facts are of general historic interest.

Dairying in ancient Mesopotamia. The oldest written records of man go back to three ancient cultures, those of Mesopotamia, ancient India, and Egypt. Of these the cuneiform writings of the Sumerians of old Mesopotamia are generally regarded as the oldest, going back to 6000 B.C. From these writings and from ancient drawings and carvings, particularly a recently found relief frieze, it is apparent that dairying was highly developed by the ancient Sumerians. The relief frieze found in the ruins of a temple in Ur of Mesopotamia and said to date back to 3100 B.C. depicts the act of milking and the handling of milk. (Fig. 1.) From this one sees that the cows were small and had short horns and small udders. These cows were milked from behind—a procedure still followed by many African tribes—and a calf was placed in front of the cow during the milking. Both of these practices were supposed to induce the cow to let down her milk. At the left the milk is being poured from the flasks (into which it was drawn) into a funnel, presumably a strainer. Two other vessels are seen—one that might be a churn, and another with a pointed bottom which Huber suggests is used for the storage of butter. The presence of two attendants in priestlike garb suggests the association of the dairy with the temple. Other records indicate that the Sumerians fermented milk—a practice still followed by the people of Eurasia—and on the basis of all available evidence, the Sumerians are credited as the first to make butter.

Martiny

Fig. 1. Ancient dairying and mythology. (*Upper*) Reproduction of a relief frieze found in the ruins of a temple in Ur and said to date back to 3100 B.C. (*Lower*) Depicting the myth of old India in which the sea of milk is churned.

Dairying in ancient India. Sanskrit, the ancient language of India, has handed down information about the early use of dairy products in that civilization. Records dating back to 2000 B.C. indicate that the people of India were raisers of cattle, and particularly of dairy cattle. Butter was used both as a food and as the most holy offering to the gods of ancient worship. The cows then, as today, were considered holy and had free run of the cities and countryside. Even the cow urine was considered holy, and was sprinkled on the face each morning by the devout.

From ancient India come the first records of evaluating dairy cows on the basis of their milk-producing abilities. The Hindu, who was one of the largest users of butter in ancient times, was probably the first to use a twirling butter churn.

Dairying in ancient Egypt. The ancient Egyptians left evidences of their interest in dairying in their writings and carvings, and in remains in tombs. Milk, butter, and cheese were used by the Egyptians as early as

3000 B.C. The opening of ancient Egyptian tombs has unearthed numerous carvings portraying cattle and dairy practices. In a tomb dating back to about 2500 B.C. an alabaster vase was found that contained butter oil. From the carvings found in the early tombs are revealed the types of cattle, ways of milking, and other interesting facts. The Egyptians milked cows from the side rather than from the rear, as did the ancient Sumerians; but like the Sumerians they placed the calves in front of the cows during milking with their front legs tied. Three different types of cattle are portrayed: hornless, short-horned, and long-horned. Marked differences in the sizes of udders indicate probable great variation in production ability. The ancient Egyptians also deified cattle. The god "Ptah" revealed himself as a bull.

Old Testament references to dairying. When the Israelites followed the Sumerians, dairying retrogressed, yet the Old Testament has some forty references to cattle. References to milk, butter, and cheese are also found, of which the following are noteworthy:

> Book of Genesis 18:8: "And he took butter, and milk . . ."
> Judges 5:25: "He asked for water and she gave him milk . . ."
> King David, in Psalms 55:21, said: "The words of his mouth were smoother than butter . . ."
> Isaiah 7:22 mentions milk and honey and butter as food.

In the First Book of Samuel, Isaiah ordered his son, David, to take ten cheeses to the captain. This book also refers to the bringing of fermented milk and one sheep and cow's milk cheese to King David. It is now generally believed that the word butter as used in the Old Testament did not refer to butter but rather to a soft cheese.

Dairying in ancient Switzerland. While there are no written records to bring us the facts, excavations indicate the existence of an ancient culture in what is now Switzerland. These people who dwelt along the lake shores were known as "Lake Dwellers." Excavations have revealed not only many skeletons of cattle but also cheese making equipment that is estimated to date back to 4000 B.C.

Roman and Greek dairying. The Greek records go back to about 1550 B.C., and the Roman records to 750 B.C. Numerous writers of both Greece and Rome have left rather complete records, particularly toward the beginning of the Christian era. Milk and cheese were important parts of the diet of these people, but most of the milk used came from goats in ancient Greece and from sheep in ancient Italy, and apparently very little from cows. Butter was not used as food but only as ointments and medicants. Hippocrates (460–377 B.C.), the noted physician, prescribed butter as a salve for burns and wounds. Gallemus (A.D. 131–201) also classed butter as a medicant, prescribing it for baths. The art of cheese making was well developed, and many treatises were written on the subject. Winkler lists six or seven great agricultural writers from about 500 B.C. to

the Christian era who dealt extensively with the making of cheese. Many different types of cheeses are listed, and it is interesting to note that Columella, writing about 60 A.D., describes the making of cheeses with spices added, such as chives, peppergrass, dill, and savory.

While the Romans and Greeks did not use butter for food, their neighbors about them did. Herodat (484–425 B.C.) describes the making of butter for food by the Scythians. They shook mare's milk in hollow tree trunks until "butyron," as they called butter, gathered on top, after which the buttermilk was curdled for cheese. The probable reason for the Romans and Greeks not using butter is that they had a great deal of olive oil to use. Butter as a food in Italy is not even mentioned as late as the thirteenth century.

Dairying from the beginning of the Christian era to modern times. This discussion is confined mainly to Eurpoe, as no particular development or advancement of dairying took place in Asia or Africa during this time. By the beginning of the Christian era milk and cheese were used for food throughout Europe, but butter was, in the main, reserved for ointment purposes. Milk cattle were to be found all over Europe in the early part of this era, and cheese making was well developed in Gaul (France), the Netherlands, and Helvetia (Switzerland). The earliest reports of the extensive use of butter are of the Celtic people in Ireland in the fifth century. These people packed butter in casks and buried it in the peat bogs for "ripening," and occasionally, even now, some of these casks are unearthed with the butter still in a good state of preservation. In the seventh century in France cheese was a common article of the diet, but butter was used only by the upper class. Norway, the first country to use butter extensively, began using it in the eighth century. She was also the first country to export butter, in the thirteenth century, and was followed by Holland in the fourteenth century.

In 1412 the butter coming into Paris was mixed with garlic. The production of quality butter began in Holland, this butter soon becoming famous all over Europe. Winkler tells of the cheese consumption in Switzerland cloisters in the twelfth to fourteenth centuries. These data show that the per capita consumption of cheese was between 25 and 50 kilograms per year. Apparently cheese consumption was the highest in history during this period, starting to decline at the beginning of the seventeenth century, when butter consumption began to increase. At this time the rotating churn, developed in Flanders, gave an added impetus to butter making.

One of the great shifts in dairying, therefore, was the development of the butter production with a small decline in cheese. Excluding the invention of the rotating churn and the development of a system of cleanliness, there were no marked changes in the dairy development until after the middle of the nineteenth century. Long before the nineteenth century many famous cheeses were developed, such as the Roquefort cheese, known in 1078; Brie, in 1500; Cheshire, in the twelfth century; Emmentaler, long before this; and Schabzieger, in 1464.

Dairying in the beginning of the nineteenth century. In order to realize the tremendous changes that have taken place in dairying in recent times one must consider the dairy practices at the beginning of the nineteenth century. While the dairy cows were more highly developed than in the periods past, there were no purebred breeds as known today. Very little was known about scientific feeding or management. Milk was used as fluid milk or made into cheese or butter; there were no other dairy products.

Fluid milk. The market for fluid milk and cream was very limited because the per capita consumption was low and people living in towns and even cities kept the "family cow," which was pastured adjacent to the town. Since the transportation facilities were limited to horse and wagon, it was necessary that the farms producing milk be located near the market. The producer did his own delivering of the milk. All milk sold was raw and was measured from a large container into whatever the purchaser provided as a receptacle.

Butter. All butter was churned on the farm where it was produced. The milk was set in shallow pans in a cool place to permit the cream to rise to the top, when it was skimmed. The cream was ripened by natural "souring," which was often speeded up by the addition of "sour" buttermilk. The churns varied from the plunger type to numerous variations of the rotating types; all of them, of course, were propelled by human power. The butter varied greatly, most of it being of inferior quality. The production was the greatest in the spring when the cows were on pasture, and, as there were no refrigeration facilities for storing surpluses, a demoralized market resulted. The size of the dairies was limited; this limitation was due to the fact that a large amount of space was required for pans for setting the milk, and to a number of other factors.

Cheese. All cheese, like butter, was made on farms. Because only fresh milk could be used for cheese making and a large amount of milk was required for a single cheese, several neighbors having but small amounts of milk frequently pooled their supply in the making of cheese. Other farms having enough milk made cheese daily. The rennet used was extracted on the farm from calves' stomachs and, therefore, varied greatly in strength. Like butter, cheese, too, varied greatly in quality.

Dairying today. Dairying today is in marked contrast to that of a hundred years ago in the improvement of the cattle and the management practices on the farm. The increased use of dairy products, the gradual disappearance of butter making and cheese making on the farm, the development of many new dairy products, the establishment of factories with sanitary practices, the specialization both on the farm and in the factory, the multitude of scientific devices used in the standardization of quality, and the well-established marketing systems are examples of the progress that has been made.

Fluid milk. Market milk is today produced mainly on specialized dairy farms under sanitary conditions specified by rigid milk ordinances. Some is sold as raw milk, as Grade A, Grade B, and as certified, under rigid

inspection; but the major portion is sold as pasteurized milk. It is sent into great processing plants where it is standardized, pasteurized, and bottled, later to be delivered at the doorstep of the consumer.

Milk for fluid consumption may now come from several hundred miles distant. It is shipped by truck or train in cans or glass-lined tanks. While milk may come from long distances, the producers of market milk are usually concentrated around the large consuming centers, although they are not as close as they were years ago. Cream frequently comes from more distant areas than does the market milk. Surplus milk in market milk areas is used for various by-products, being sent to large concentration plants equipped to manufacture various products from milk.

Butter. The manufacturing of butter is now done, in the main, in modern factories employing skilled butter makers. The cream is produced on the farm from the skimming or separating of milk and is brought to the factory by truck. In the most modern factories, careful chemical and biological control measures are employed in neutralizing, pasteurizing, ripening, and churning the cream and in packaging the finished product. As a result, the chemical composition of butter has been standardized and the quality has been greatlv improved.

Cheese. Cheese making, likewise, has been transferred from the farm to plants located in the cheese-producing areas where skilled cheese makers are employed. Here, too, technical control measures are used in the various phases of manufacturing and curing cheese. Much of the cheese produced finds its way to processing plants where, through patented processes, it is reworked, blended, and flavored with various flavoring materials, to be sold under various trade names. Such products are usually referred to as process cheese. In recent years most of the more popular foreign types of cheese have been successfully reproduced in this country.

Other dairy products. The most outstanding changes in the dairy industry have been the development of a number of other products and of uses for them. This had its beginning with the condensing of milk in 1856, followed by the manufacturing of dried milk and milk products and the manufacturing of casein, lactose, and ice cream. Some of the largest dairy plans, are those engaged in manufacturing these products, none of which were known a century ago. The use of these products has greatly extended the dairy field, and a much greater extension is anticipated through further development of uses for dried milk and milk products.

Factors responsible for modern dairying. There are numerous reasons for the changes that have taken place. The relative contribution of the different factors are varied and difficult to evaluate, and in some cases it is not clear which is the cause and which is the effect. The contributions of science and education are the most noteworthy, and under this heading, not in sequence of importance but for the convenience of discussion, they may be listed as the following factors:

1. Improvement of dairy cattle
2. Development of scientific feeding and management

3. Development of the science of nutrition
4. Development of bacteriology
5. Development of chemistry
6. Inventions
7. Development of agricultural education
8. Extension and other educational and promotional organizations
9. Development of marketing organizations

Many of these factors have contributed to an increased consumption of dairy products, and an increased consumption of dairy products, in turn, has become an incentive to furthering scientific investigation. A brief summary of each of these factors is made at this juncture.

Improvement of dairy cattle. The great improvement of dairy cattle is shown by the following table, which gives the average annual production per cow in pounds of milk.

AVERAGE ANNUAL MILK PRODUCTION FOR COWS IN THE UNITED STATES

Year	No. of Cows	Pounds
1910	20,625,000	2,902
1917	22,894,000	3,716
1921	21,408,000	4,336
1925	21,508,000	4,218
1930	22,218,000	4,508
1934	25,198,000	4,033 *
1935	24,187,000	4,184
1940	23,677,000	4,625
1945	25,329,000	4,797
1948 **	22,935,000	5,036

* The lower production per cow in 1934 is due to the extensive and severe drought of that year.
** 1948 figures are preliminary.

The stimulus for improvement came from the formation of the breeders' associations for the various breeds, beginning about 1860. Men of influence in political and business affairs then became interested in breeding and importing superior stock. Prentice suggests that Darwin's work, *The Origin of the Species*, which appeared in 1859, was also a factor, since it gave hope for the evolution of superior forms of dairy cattle. The first private record was made in 1870, of a Holstein. Records were later developed into official testing. Subsequent making of world's records did much to make dairymen conscious of the desirability of high production. Sons of high producing dams came into great demand, and while this is not the best method of selecting superior germ plasm, it did much to improve dairy cattle.

The development of interest in the show ring and public production contests held at fairs, both of which were supported by the breed association beginning in 1870, must also be credited with material influence on the improvement of dairy cattle. The work of the great English breeders, Bates in improving the dairy quality of Shorthorns, and Dauncey and

Duncan in establishing a larger Jersey, also had its effects. At present the application of the principles of the science of genetics to dairy-cattle breeding is effecting still further improvement.

Development of scientific feeding and management. The steady increase in average production per cow must be attributed not only to improvement by breeding, but also to improved feeding and management. The fundamental work by many workers on the nutrient requirements for cattle, which took form in what is known as feeding standards, focused attention on feeding and the need for adequate nutrient intake of cows for milk production. This resulted in better feeding and higher milk production. The establishment of experiment stations where numerous trials were made of the effects of various rations and management practices upon milk production must also be listed as an important factor in increased milk production per cow.

Development of the science of nutrition. The fundamentals of proper nutrition have long been under investigation, and many of the findings have aided the promotion of dairying by showing the high nutritive value of milk and its products. The greatest impetus given by this science to the dairy industry was through the discovery of vitamins and the realization that milk is a good source of these nutritional elements. Following this, much work has appeared on the high nutritive value of milk and its many products. The value of the scientific evidence in favor of milk as a food has been no small factor in increasing consumption. As a result of all the work done, milk has been shown to be the most nearly perfect food, one that is practically indispensible for children.

Development of bacteriology. The discovery of microorganisms in milk in 1841 by Fuchs marks an important point in the development of dairying. No other science is more intimately associated with dairying, from the production of milk on the farm to the manufacturing and handling of all dairy products, than is bacteriology. Through this science dairying has learned the control of organisms that deteriorate dairy products and the development of organisms essential to the manufacture of those products depending upon micoorganisms, such as cheese, cultured milks, ripened cream, and many others.

The discovery of pasteurization by Pasteur is hailed as having had a more profound influence upon the dairy industry than any other single discovery.

Development of chemistry. Without the contributions of the chemist it would be impossible for modern dairying to exist in its present form. Milk is bought and sold on the basis of its fat content as determined by the Babcock test, which was developed in 1890 by Babcock. (The Gerber test, which was discovered about the same time, is used in Europe.) Nearly all dairy products must meet standards of composition, all determined by chemical methods. In addition to tests for fat, tests for acidity, total solids, casein, and lactose are commonly used. There are also many tests for purity and deterioration of the various dairy products, used by control agencies. These tests are of incalculable value in detecting and preventing

adulteration of dairy products. Chemistry is also indispensable in the development of the many processes used in making different dairy products.

Inventions. Of inventions that have had an important bearing on the dairy industry the Babcock test has already been mentioned. Another is the centrifugal separator invented simultaneously in 1878 by Winstrup and Nielsen, and DeLaval; this separator did away with skimming by hand and permitted larger dairies. The inventions of condensed milk, made by Gail Borden in 1856, and of equipment for drying milk by both the drum and spray processes have opened a new outlet for dairy products. The invention of artificial refrigeration and the establishment of cold-storage plants have been very effective in leveling out prices throughout the year by permitting the storing of surpluses of peak production periods. The perfection of railroad refrigeration permits shipping for long distances. To these must be added the invention and development of the milking machine, cooling devices, churns and workers, pasteurizers, homogenizers, clarifiers, ice cream freezers, automatic bottling and carrying equipment, bottle and can washers, and a host of other pieces of equipment that are now taken for granted and without which the industry would be very different.

The first factories. The factory system which is so characteristic of the modern dairy industry is of comparatively recent origin. The first cheese factory was established in 1851 by Williams in Oneida, New York. In 1871 the first creamery was established by Stewart in Iowa. The first condensery was built in Massaic, New York, in 1856. The first milk-drying plant was built in Fayetteville, New York, in 1905. The first co-operative creamery was started in Clarks Grove, Minnesota, in 1890.

Education. Education has influenced dairying in two ways: first, in training people for the technical work in the production and in the processing of dairy products; and second, in teaching people the value of dairy products as food. The former function of education has been instrumental in bringing about more economical production and greatly improved quality of the products. The latter has been a big factor in the increased consumption of dairy products.

Education is effected through many agencies. The most important are the agricultural schools and colleges that train and educate large numbers, many of whom become teachers of vocational agriculture in secondary schools and county agricultural agents, who with the extension experts of the various states carry the knowledge to the masses. Breed associations, state dairymen's associations, state dairy councils, and the National Dairy Council all carry on educational campaigns for the increased use of dairy products; these campaigns have been very effective.

The agricultural press, too, has been an important factor in the development of dairying. Through its medium many of the development programs have been sponsored. Much credit is due them for disseminating the findings of experiment stations.

The first dairy school was organized in Germany near Berlin in 1717.

Prior to that time and dating back A.D. 300 to 400 the monasteries were the chief sources of information on matters pertaining to dairying. In the United States the first state agricultural college was established in Michigan at Lansing by an act of the State Legislature, February 12, 1855. In 1853, the New York Legislature incorporated "The New York State Agricultural College," but the institution was not established until 1868 when Cornell University was founded.[1]

Development of marketing organizations. With the development of the dairy industry to take care of the increasing demand there were periodic surpluses which resulted in demoralization of prices and loss of market for many. In order to cope with this situation, milk producers' associations were formed around most large milk-consuming centers. These associations attempted to stabilize the market by regulating the amount of milk going to the market and by removing surpluses for by-products. In Minnesota, where the co-operative creamery movement started, a large number of the co-operative creameries joined into what is known as the Land O' Lakes Co-operative Creameries for marketing their output. In Wisconsin the cheese producers have a similar organization for the marketing of cheese.

[1] TRUE, ALFRED CHARLES. History of Agriculture Education.

Chapter 2

ECONOMICS OF MILK PRODUCTION[1]

IN MAN'S STRUGGLE FOR EXISTENCE HE SOON LEARNED TO DEPEND UPON domesticated animals and plants for the major part of his food supply. One of the first animals developed for this purpose was the cow. As man has forged ahead in his methods of living he has become more and more dependent upon cows' milk as food, until today milk and milk products constitute an essential part of his diet. As a means of satisfying a greater number of his wants man has learned to resort to specialization in the production of goods. Through the development of specialized production, the dairy industry, which has for its purpose the supplying of his needs for milk and its products, has evolved as a substantial part of his economic system.

At first dairying, like every other industry, was relatively simple. The milk was merely obtained from the cow and consumed in its raw state. But this is in decided contrast to dairying as it is practiced today in the United States. The influence of specialization has affected the dairy industry to the extent that the obtaining of milk is now just the first step in the complex process of producing dairy foods. With the gradual development of large centers of concentrated population that are dependent upon outside and often remote sources of food, the dairy industry has become divided into separate and distinct production stages. Under the old system all the functions of the industry were performed on the farm. Under the present production system most of the processing functions are carried on in specialized plants, and the farmer is permitted to concentrate upon the production of raw milk only. Thus, dairying is now conducted, for the most part, by assembling the milk obtained from many farms into processing plants from which the products emanate into the distribution system.

The organization of the dairy industry is extremely complex. The raw material, milk, is produced under the many diverse conditions existing on all types of farms. From this source it takes numerous courses in reaching the ultimate consumer, who may buy it in many forms and products. To simplify the discussion of the dairy industry it must be divided into convenient parts, the first of which is logically the production of milk. Therefore, this chapter will deal with the economics of milk production in the United States, and the following seven chapters will be concerned with dairy products.

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[1] Harry C. Trelogan, Ph.D., Assistant to the Administrator, Agricultural Research Administration, U. S. Dept. of Agr., contributed this chapter.

DEMAND

Production of any product takes place only if it satisfies a demand, and it is most likely to continue if it is in response to an indispensable need. Man's most urgent need is food, and of his different kinds of food, milk and its products, taken as a whole, are among the least dispensable. For this reason the permanency of the dairy industry is assured.

The size of the dairy industry, however, is subject to some change, depending upon variations in demand for its products. Demand for milk is derived from the demands for all dairy products, such as market milk, butter, cheese, and ice cream, which people desire and consume to a greater or lesser degree according to circumstances. When all these constituent demands are considered it is found that the primary factors which influence the total demand for milk are (1) number of consumers, (2) their customs and habits of consumption, and (3) their ability to buy what they want.

Population. The number of people in this country has increased very rapidly. The present rate of growth, however, is lower than during the early development of the country, so future increases in demand for milk due to this factor will not be so pronounced as they have been in the past. No decrease in population is anticipated within the near future, so demand for milk will hardly decline from such a cause, but is likely to increase for some time to come.

Habits of consumption. With the increased knowledge of nutrition revealed by scientists in the last several decades, the value of milk and its products in the diet have been recognized more fully than ever before. As information concerning energy value, vitamin content, and digestibility of foods has been divulged, milk has been rated most favorably. Results of repeated experiments substantiating its value have been widely publicized, and as effective educational methods have been used to disseminate these facts, dairy products have acquired a more prominent place in the consumer's diet. Approximately one-fourth the weight of food consumed by the average person is now made up of milk products. The per capita consumption of these products expressed in terms of milk equivalents is about 94 gallons or a little more than 800 pounds a year.

While consumption of different dairy products has changed to a marked degree, total per capita consumption of milk and milk products has been subject to relatively little change from one year to another, rarely fluctuating by more than 2 or 3 per cent except during war years when diversions to overseas use caused abnormal reductions in domestic consumption. This indicates that total demand for milk is relatively constant compared with other foods.

Ability to buy. The ability of consumers to buy dairy products depends upon the relationship between the prices of these products and consumers' incomes. As incomes increase, people tend to spend more for dairy products and thus increase the total demand for milk. Although low income groups tend to spend a greater share of their incomes for these

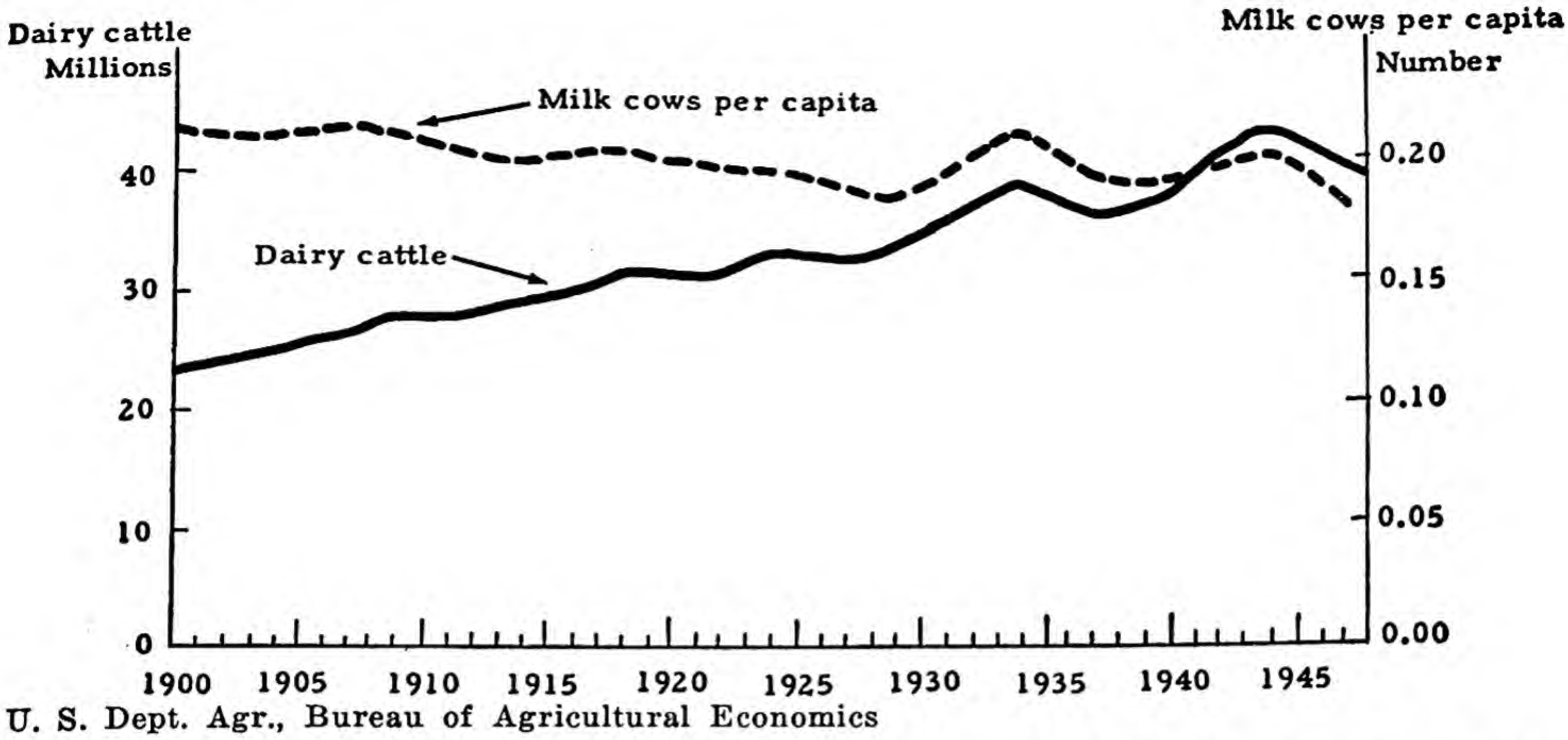


Fig. 2. Total number of dairy cattle and the number of milk cows per capita, U. S., January 1, 1900 to 1947 inclusive.

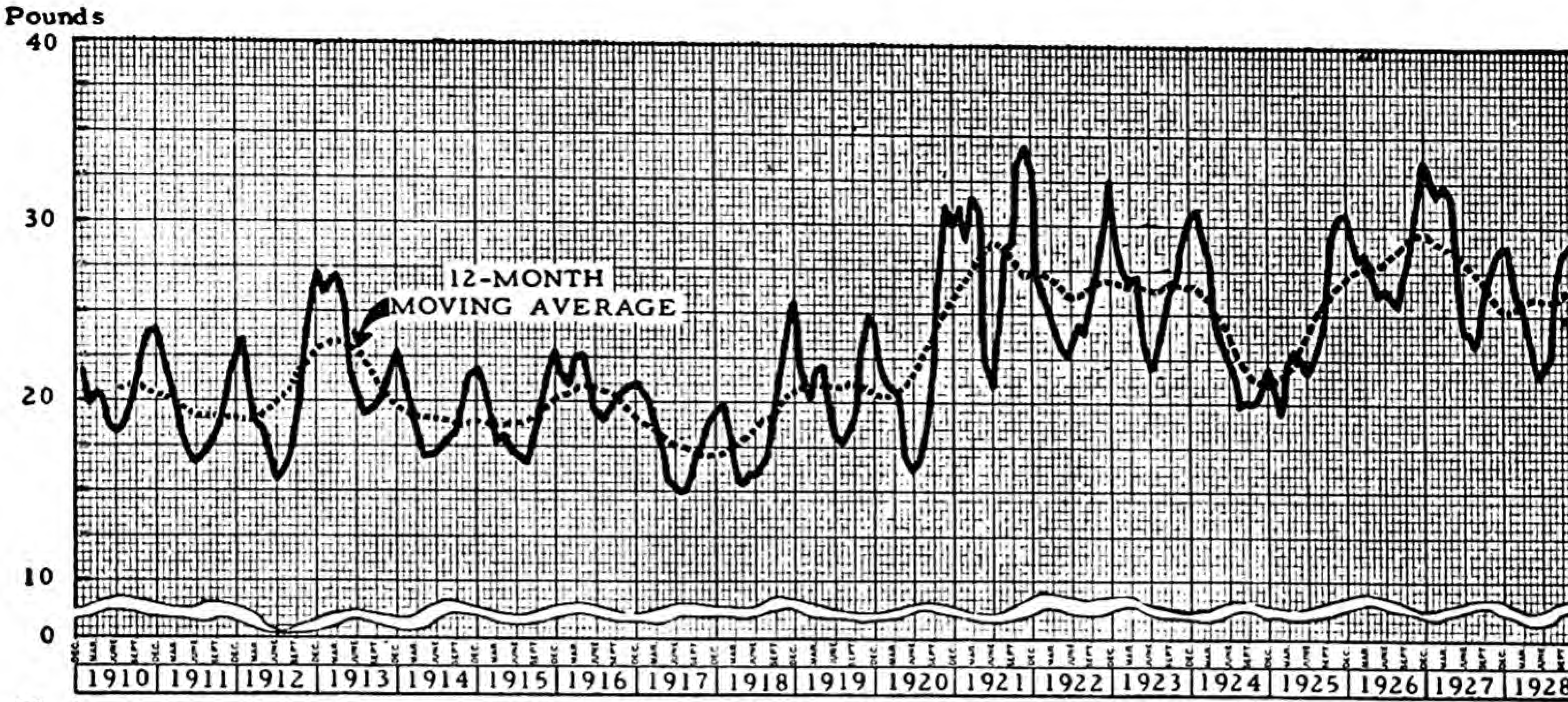
products, their total expenditures per family are less than those of consumers in the higher income brackets. This would indicate that as incomes rise or fall dairy products prices must rise or fall accordingly in order to maintain consumption at the same level. If prices of dairy products are kept high relative to the income level, they will have a gradual depressing effect upon the demand for milk in spite of the effects of favorable publicity and advertising designed to increase consumption. Low prices, of course, would have the opposite effect, but consumption of milk will be most stable if prices of dairy products are flexible enough to react quickly to changes in demand caused by changes in consumers' incomes.

SUPPLY

In response to the demand for milk and dairy products in the United States nearly five million American farmers keep cows. They produce about 120 billion pounds of milk each year, of which some 3¼ billion pounds is sucked by calves and spilled or wasted on farms. The remainder, plus some 2¾ billion pounds of milk produced by cows not on farms, leaves a total supply of some 119 billion pounds of milk available in this country. The number of cows and the production per cow determine the amount of the supply.

Number of cows. There were on January 1, 1949 about 24.5 million cows and heifers two years of age and over. It is estimated that the total number of dairy cattle (including, besides the cows, the bulls and the replacement stock of calves and heifers under two years of age) was 38.0 million head. In addition to these there was a large number of dual-purpose and beef cattle that could produce milk on occasion, but nearly half of the 78.5 million cattle on farms on January 1, 1949 were kept primarily for dairy purposes.

A rather steady increase in the total number of dairy cattle has charac-

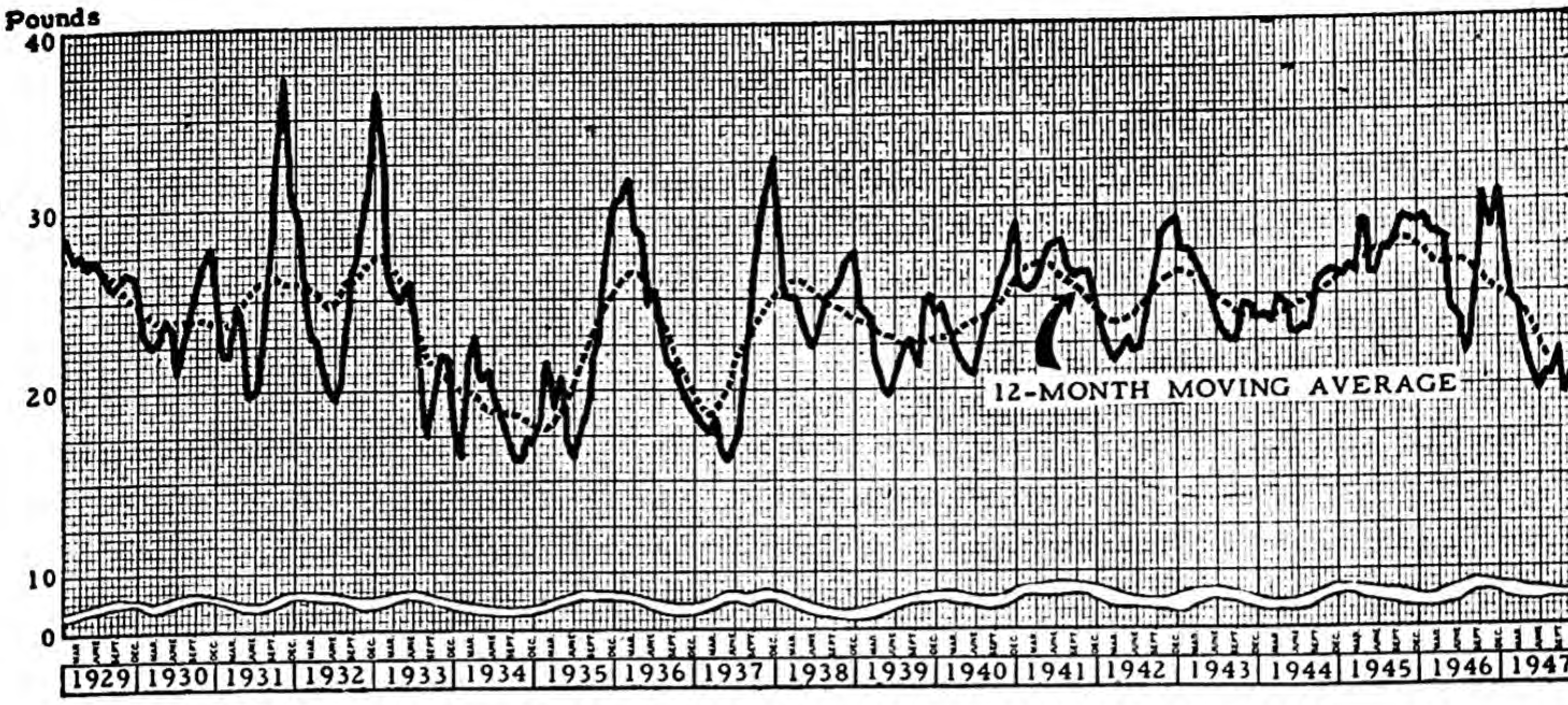


U. S. Dept. Agr., Bureau of Agricultural Economics

Fig. 3. This graph shows the pounds of feedgrain one pound of butterfat will buy; U. S. average, based on farm prices. These same data are shown

terized the history of dairying in this country. (Fig. 2.) This increase can be accounted for, in the main, as a response to the demands of a growing population. Within the last three decades, however, four periods of decline have occurred. Only slight decreases occurred in 1921 and the period from 1925 to 1928, but a significant decline began in 1934 and continued to 1938, and another significant decline began in 1945, extending through 1948. With the population of the country leveling out, these periods of alternating increases and decreases in dairy-cattle numbers are more apt to occur in the future. Several factors which may affect these fluctuations can be distinguished because of the influence they have had in the past. They include (1) prices of dairy products, (2) feed supplies, (3) cyclical fluctuations, (4) abnormal circumstances, and (5) government programs.

Prices. Since prices tend to bring the supply of milk coming to market into equilibrium with the demand, farmers attempt to adjust their production according to the existing price. That is to say, when the farm price for milk is high farmers tend to produce more, and, conversely, to produce less when prices are low. Since a fairly definite margin exists between the farm prices of milk and the prices of dairy products there is a close relationship between the two, and the farm milk price is, in a sense, a reflection of dairy products prices on the retail market. But the actual milk price is of little consequence; it is the relationship between the farm price of milk or butterfat and the farm prices of other agricultural products that influences farmers to expand or contract their dairy production by keeping more or fewer cows. Dairy prices tend to be more stable than the prices of other agricultural products. Consequently, when the prices of all agricultural products fall, the farmers usually keep more cows because their milk prices do not go down so rapidly or so far as the other prices. This fact was well illustrated in the beginning of the last depression. Between 1929 and 1933 the index of farm prices for dairy products declined



in a different form in columns 2 and 5 of Table VII in the Appendix.

only 54 points, while the grain price index fell 76 points. During this same period the number of dairy cattle on farms increased from 33.5 million to 39.0 million head. The opposite situation occurred after 1944 when cow numbers declined despite rising prices, because other prices tended to rise more rapidly and further than dairy prices.

Feed supplies. Feed supplies have a direct effect upon the number of dairy cattle maintained on farms. When feed supplies are plentiful, with resultant low prices, farmers find it more profitable to convert the feed into animal products than to send it to market directly. From 1921 to 1933 the prices of feed grains were low compared with those of dairy products, but after the droughts of 1934 and 1936 this situation was reversed and feed grains were relatively higher in price. This relationship helps to explain the changes in cow numbers that occurred during these periods. The butterfat-feed ratio illustrated in Figure 3, which expresses the pounds of grain required to buy one pound of butterfat, is a useful tool for following this relationship from year to year.

Cyclical fluctuations. Some evidence has been presented by statisticians to show that a cyclical fluctuation in the rather steady upward trend in cow numbers has occurred in the past. Within the last two decades this cyclical fluctuation in dairy-cow numbers has become pronounced and evidently follows closely the beef cattle cycle which has long been recognized. The existence of cyclical changes in the numbers of other livestock on farms, notably hogs, sheep, and poultry, is further evidence that such fluctuations in dairy cattle may be expected to become more clearly defined in the future.

Cyclical changes in livestock numbers are engendered by farmers adjusting the size of their herds in response to price changes. Once started, the cyclical pattern is established and explained on biological grounds. Cow numbers cannot be increased rapidly because it takes several years

from the time cows are bred until heifer calves are raised to maturity. Consequently, the dairy-cow cycle may be expected to resemble the beef-cattle cycle, which is about 14–16 years in length.

Abnormal circumstances. Violent disruptions in the economic system caused by natural forces, such as irregularities of weather, or by human activities, such as wars or depressions, have marked effects upon the cattle population. They are placed under the category of abnormal circumstances because their influence is usually brought to bear indirectly through prices, feed supplies, and the like. The effects, best illustrated by the stimulated production during the last two wars and contracted production during the drought of 1934, are quite drastic and continue to influence cattle numbers for years afterward. The interrelationship between casual factors often makes the exact magnitude of their separate effects indeterminate, but the original stimulus is easily traceable to the underlying cause. On the assumption that history repeats itself, dairy farmers must be alert for these unpredictable but recurring circumstances and anticipate their results.

Government programs. Government programs designed to assist farmers in making necessary adjustments in production have also had significant effects on dairy cattle numbers. Most notable of these have been the disease-control programs combating tuberculosis and Bang's disease. In the 20 years from 1927 to 1947 nearly four million tuberculosis reactors, the majority of which were dairy cattle, were exterminated. The number of cattle eliminated for this reason, however, has dropped to small proportions in recent years. Slightly more than three million dairy cattle were slaughtered in the Bang's disease eradication program from 1934 to 1947. The Government emergency livestock purchases after the drought of 1934 also reduced the number of dairy cattle by an estimated one and one-half million head. In addition to these governmental activities that have had direct effect upon dairy-cattle numbers, other agricultural programs, such as that of the Agricultural Adjustment Administration and the Soil Conservation Program, have affected them indirectly through influence on the amount and quality of feed supplies and on agricultural prices in general. These programs are apt to increase dairy-cow numbers in the future as they make more feed, especially roughage, available for conversion to animal products.

Milk production per cow. The total supply of milk can be varied a great deal without any change in the number of cows by effecting changes in the production per cow. Annual average milk production per cow was 4,475 pounds in the ten-year period, 1934 to 1943. By 1948, it reached 5,000 pounds for the first time. Most of the variation in annual production per cow which has fluctuated within a range of 1,000 pounds over the past 20 years is attributable to changes in feeding practices of dairy farmers. Dairymen tend to use more roughage and pasture and less concentrate feeds when the butterfat-feed ratio is low.

While favorable price ratios induced farmers to feed more concentrates than ever before following World War II, part of the recent increase in

production per cow is explained by improved breeding and feeding practices. Dairy herd improvement programs, the use of proved sires and artificial insemination, and the adoption of soil conservation measures resulting in higher quality hay and pastures have all contributed. Advances due to these causes may be expected to be durable and to be continued.

A much greater fluctuation in the average production per cow is entirely possible. This is indicated by the differences between sections of the country and by the record of cow testing associations.

As may be noted in the table below, annual average milk production per cow in the Western states is nearly 6,300 pounds while in the South Central states the average is little more than half, or 3,322 pounds. This variation is partly due to differences in the milking quality of the cows, the amount and quality of feed, and the proportion of milk sucked by calves—factors which farmers could readily adjust if their desire to produce more or less milk were urgent.

ESTIMATED MILK PRODUCTION PER COW BY SECTIONS OF THE COUNTRY 1934 AND 1947 [1]

Section *	Year	
	1934	1947
North Atlantic	5,161	5,591
East North Central	4,613	5,675
West North Central	3,769	4,898
South Atlantic	3,250	4,112
South Central	2,741	3,322
Western	5,177	6,292
United States	4,033 **	4,997

* In this and in future references these sections include the following states:
North Atlantic—Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania.
East North Central—Ohio, Indiana, Illinois, Michigan, Wisconsin.
West North Central—Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas.
South Atlantic—Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida.
South Central—Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, Texas.
Western—Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Oregon, California.
** The lowest production per cow in more than 20 years.

In so far as variations between areas are caused by differences in the breeds of cattle and in types of dairying practiced, they are less susceptible to adjustment and will always exist. Nevertheless, the differences need not be so great, and there is ample room for increased production even in those sections with the present high averages.

When it is realized that record cows are producing over 35,000 pounds of milk in a year, an average annual production of 5,000 pounds seems pitifully small. Naturally the average could not be expected to approach the record figures, but some idea of how much it could be raised in practice can be estimated from the performance of herds on the records of the cow-

[1] Bureau of Agricultural Economics, U. S. Dept. Agr.

testing associations, which are kept to assist farmers in identifying their poor cows so that they can be culled out. In 1920 these tested cows produced on the average 5,989 pounds of milk and 247 pounds of butterfat. By 1944 the average production of 561,587 cows had been raised to 8,296 pounds of milk and 336 pounds of butterfat.

Another indication that points to possible future increases in milk production per cow through breeding and similar programs is obtained from the table below which compares progress made with several agricultural commodities.

PRODUCTION PER UNIT OF SELECTED FARM PRODUCTS, ANNUAL AVERAGES 1925–1929 AND 1945–1946, WITH COMPARISONS

Product	Unit	1925–1929	1945–1946	Per Cent Increase
Potatoes	Bushels per acre	113.6	169.6	49.3
Tobacco	Pounds per acre	773.4	1,124.0	45.3
Cotton	Pounds per acre	171.1	242.2	41.6
Corn	Bushels per acre	26.4	34.9	32.2
Eggs	Number per layer	93	118	26.9
Butterfat	Pounds per cow	174.0	192.7	10.7
Milk	Pounds per cow	4,437	4,844	9.2

Breeding research and experimentation with large animals such as dairy cows is very slow and expensive compared with small plants or animals. It takes at least five years from the time of conception to get a measure of productivity of the offspring of a dairy animal compared with less than two years for an annual plant or a bird, such as a chicken. Consequently, the adoption of the same genetic principles and practices would naturally bring much slower results with dairy cows and bulls. Further application to dairy cattle of the methods demonstrated with small plants and animals promises still higher production per cow in the future.

Since a point is reached in the feeding of cows beyond which further increases in milk production can be obtained only at costs that exceed the value of the milk, it must not be inferred that greater production per cow is in itself a desirable goal. Instead, dairymen should seek the optimum production point at which highest profits can be obtained. Production records have clearly demonstrated that cows with inherited characteristics for high milk production are the most profitable animals to feed. For this reason the conclusion is drawn that a higher average production per cow is desirable. Too much emphasis should not be given to high production records for individual cows that have been obtained by feeding to the utmost without regard to cost. The performance of an entire producing herd is of more significance than the performance of one or a few selected animals. In general, dairymen stand to benefit more through elimination of low producing "boarder" cows from herds than they do from the intensive feeding of all cows.

Cows per capita. The number of cows per capita has followed a declining trend since 1900, averaging well over 20 cows per hundred people

during the first half of the period and somewhat under 20 cows per hundred in the last half. (Fig. 2.) Per capita consumption of milk has been maintained over this period despite a reduction in cows per capita because of the increase in the milk production per cow that has been achieved.

RELATION OF DAIRYING TO AGRICULTURE

To comprehend the true importance of dairy production in American agriculture it is necessary to view the part it plays in the agricultural picture. This cannot be presented simply in terms of the total number of dairy farmers, cows, or pounds of milk, but requires an insight into the role that dairying plays in individual farm enterprises and the return that farmers receive from this part of their work.

Distribution of dairy cattle by areas and kinds of farms. Dairy cattle are more widely distributed on farms than any other plant or any other animal except chickens, for more than 70 per cent of the farmers keep at least one dairy cow. The principal reasons for the universal distribution of dairy cattle are: (1) they are subject to relatively little restriction due to soil and climatic conditions, (2) they offer a convenient side line for most types of farming, and (3) they are efficient producers of an essential human food.

Every part of the country has a substantial dairy-cattle population because cows are adaptable to all except the most extreme climates and are able to thrive on a wide variety of feeds. Since cows are good foragers and efficient users of roughage they have comparative advantage in those areas where the topography of the land is not suitable for extensive cultivation and where pastures are plentiful. This is a partial explanation for the fact that the cow population is most dense in the North Central states. (Fig. 4.) In other areas that are suited for specialized production of particular crops, such as cotton and tobacco in the South or wheat and corn in the Midwest, dairying is carried on more as a side-line enterprise.

As one travels away from centers of concentrated population he observes first the large dairy herds which produce market milk, next the herds which supply market cream, then the somewhat smaller herds further out which produce milk for concentrated milk products, later the cows which produce milk to be converted into cheese and butter, and finally the one- and two-cow farms where milk is produced on a self-sufficiency basis. Thus, he sees how dairying fits into extensive and intensive farming systems because of the many ways in which milk is used and the wide variety of forms in which it ultimately finds its way to market. The traveler will note, however, that the cows are not uniformly distributed about the population centers but are concentrated more in those regions that are best adapted to dairy production. As a result, the butter and cheese areas may be far removed from market centers, which are located in regions that are disadvantageous for dairying.

Dairying can be practiced intensively—that is, on high-rent land, close to the cities, where the cows are confined in large herds and fed a great proportion of concentrated feeds for high production, somewhat as

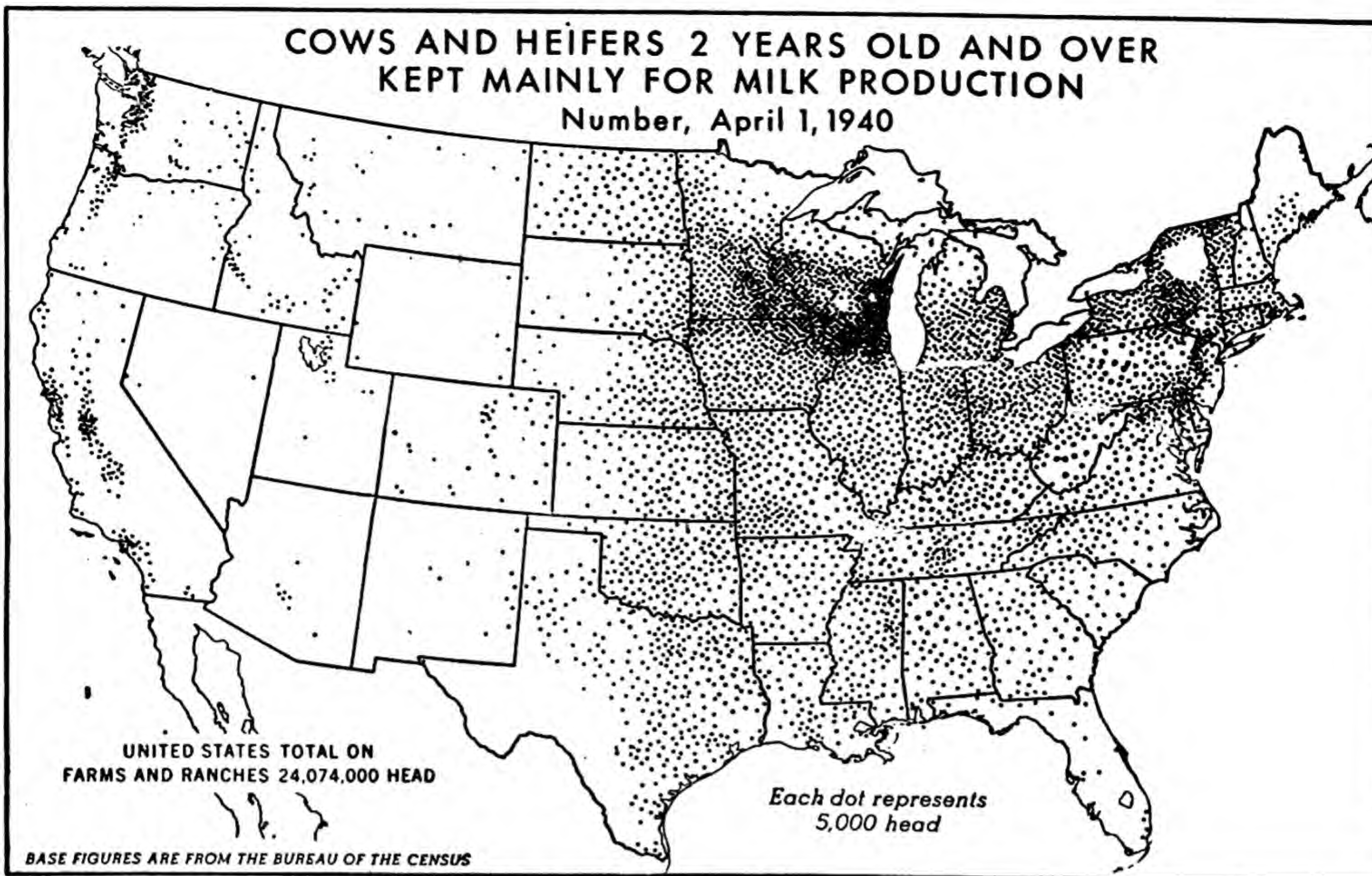


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Fig. 4. Milk cows and heifers 2-years-old and over, April 1, 1940.

machines are fed raw materials—in the production of market milk. There are, however, relatively few specialized dairy farms of this type. If it is assumed that dairy farms, strictly defined, derive more than 40 per cent of the value of their products from dairying, only about one-tenth of all the farms would qualify for this category and about 65 per cent of the milk cows would be found on other types of farms. Only 170,000 farms have herds of 20 cows or more, and less than 530,000 farms keep from 10 to 19 cows. The vast number of herds, more than three million, are made up of nine cows or less. (See table below.)

MILK COW HERDS CLASSIFIED ACCORDING TO SIZE AND PERCENTAGE OF HERDS, COWS MILKED AND TOTAL MILK PRODUCED IN EACH SIZE CLASSIFICATION—1944 [1]

	Cows Per Herd			
	1 to 9	10 to 19	20 or More	Total
Number of herds	3,783,872	526,645	170,867	4,481,384
Per cent of herds	84.4	11.8	3.8	100.0
Number of cows milked	10,632,195	6,833,999	5,290,493	22,756,687
Per cent of cows milked	46.7	30.0	23.3	100.0
Milk produced (thousand gallons)	4,902,311	4,025,798	3,791,628	12,719,737
Per cent of total milk produced	38.5	31.7	29.8	100.0

The highest proportion of the large herds is found in the Pacific Coast, North Eastern, and North Central states around the large centers of

[1] 1945 Census of Agriculture.

population. In these localities the demand for market milk is sufficiently great to justify the added expense involved in producing milk under such conditions. This is true because milk is a bulky, perishable commodity subject to sanitary regulations prescribed by city health departments which require that it be obtained from a supply area sufficiently close to the market to permit prompt delivery. As a result of the added costs involved in meeting these quality requisites, market milk usually receives a substantially higher price than milk going into other uses and this permits farmers close to the city to engage in intensive milk production.

PRODUCTION OF MILK AND NUMBER OF PRODUCING COWS BY SECTION OF THE COUNTRY, 1945 [1]

Section	Milk Production		Number of Cows	
	Million Pounds	Per Cent	Thousands	Per Cent
North Atlantic	18,778	15.5	3,228	12.7
East North Central	36,109	29.7	6,481	25.6
West North Central	28,719	23.6	6,276	24.8
South Atlantic	7,644	6.3	1,939	7.7
South Central	16,298	13.4	5,095	20.1
Western	13,956	11.5	2,310	9.1
Total	121,504	100.0	25,329	100.0

Although many smaller dairy herds are engaged in market milk production, the four- to ten-cow herds are most prevalant in the butter-and-cheese producing areas of the North Central states, where dairying is best adapted to diversified farming conditions which provide home-grown feeds and ample pasturage for the cows. Of the farmers who keep cows, nearly 40 per cent have from four to ten cows, and nearly half keep only one to three cows. The majority of this latter group is located in the Southern states where many farmers produce just enough milk to supply their own needs. Slightly more than twelve million cows are in herds milking ten cows or more, compared with slightly less than eleven million cows in herds milking fewer than ten.

Milk production and distribution of cattle by areas and leading states. Differences in the number of cows and in the milk production per cow between sections of the country contribute toward even greater differences in the amount of milk produced, because the Southwest with the smallest number of cows also has the lowest milk production per cow. As indicated in the above table, the South Atlantic states are least important in total milk production, while the East and West North Central states combine to produce over half the total milk supply.

The ten leading states in milk production are listed in the following table in the order of their importance, together with the number of producing cows located in each of these states. They produce 58 per cent of the milk with 52 per cent of the cows. It will be noted that the states rank quite differently in milk production and number of cows. Here the effect of

[1] Bureau of Agricultural Economics, U. S. Dept. Agr.

milk production per cow is striking. Because of low productivity per cow, Texas, ranking third in number of cows, is tenth in milk production. California has fewer cows than any of the other states listed and is also surpassed by Missouri and Indiana, but it still ranks seventh in milk production because of high productivity per cow.

TEN LEADING STATES IN MILK PRODUCTION AND THE NUMBER OF PRODUCING COWS, 1945 [1]

State	Milk Production			Number of Cows		
	Rank	Million Pounds	Per Cent of U. S. Total	Rank	Thousands	Per Cent of U. S. Total
Wisconsin....	1	15,442	12.7	1	2,455	9.7
Minnesota...	2	8,625	7.1	2	1,665	6.6
New York....	3	8,172	6.7	4	1,362	5.4
Iowa........	4	6,702	5.5	5	1,343	5.3
Illinois.......	5	5,777	4.8	6	1,111	4.4
Michigan....	6	5,741	4.7	8	1,027	4.0
California....	7	5,720	4.7	12	800	3.1
Pennsylvania.	8	5,404	4.5	10	965	3.8
Ohio.........	9	5,335	4.4	7	1,080	4.3
Texas........	10	4,286	3.5	3	1,410	5.6
Total	—	71,204	58.6	—	13,218	52.2

Advantages of dairying. The fact that over half the farms which maintain dairy cattle have less than one-fifth the milk cows is attributed to the complementary and supplementary advantages obtained from dairying in a diversified farming system. Diversification rather than specialization is the rule in agriculture because of the distinct advantages that are to be gained by combining supplementary or by-product enterprises with the main enterprise of the farm. These advantages include: (1) more complete untilization of labor and fixed cost elements, (2) fuller utilization of by-products, (3) reduced risk from uncertain markets and adverse weather, and (4) less transportation and merchandising cost.

Supplementary advantages. A supplementary enterprise is one that tends to make fuller use of the available production elements. Cows tend to do this in so far as they draw upon available feed and labor. Practically every farmer, from the truck gardener engaged in intensive production to the wheat grower on the extensive margin, has roughage that can be fed to livestock and converted into human food. The cow is recognized as the leading farm animal in the use of roughage. She can use hay for feed and straw for bedding, and also such other farm by-products as low-grade cereals, corn fodder, and pastures that might otherwise be wasted. She is also a good forager and adapts herself to many kinds of feed which she converts into useful and marketable food products.

The small dairy also makes efficient use of labor available on the farm. Tendance of the cow is usually classed with the chores because it does not interfere with the regular farm work. Nor does it conflict with seasonal

[1] Bureau of Agricultural Fconomics, U. S. Dept. Agr.

labor demands, since much of the labor around the dairy can be done in the winter and the slack seasons when other labor requirements are low. Thus, dairying tends to regulate labor requirements in such a way that hired help can be used the year round and, therefore, a more desirable kind of help can be employed. It has the further advantage of furnishing opportunities for employment of the whole family, thereby adding to the farm income.

Complementary advantages. Cows have complementary advantages in the farm organization because they contribute elements of production in the form of supplies: namely, food, feed, and fertilizer. Every farmer is a consumer of milk. Nearly one-tenth of the milk produced is used on farms as whole milk and cream, another 5 per cent is used for making farm butter, and about 2.6 per cent is fed to calves. Per capita consumption of milk and dairy products is higher among farm people than among city people. In many instances, cows are kept solely to supply farm requirements for milk and butter; while in others they produce a commercial surplus during certain seasons; but even when family consumption is incidental to commercial production cows have a distinct complementary relationship. In areas where cream is shipped to market either for market cream or butter, the skim milk is often utilized on the farm as feed for other livestock, notably hogs and poultry. When skim milk is fed to hogs as a feed supplement, its value per hundredweight is conservatively estimated as being equal to three and one-half pounds of tankage plus seven pounds of corn.

The importance of dairy cattle in maintaining soil fertility becomes greater after agriculture is well established. In the extensive farming practiced in new-farming areas production is often limited to soil-depleting crops, such as cereals, because farmers are not immediately confronted with the need for soil conservation. But as farming continues and becomes more intensified the fertility of the soil must be restored and maintained. Here dairy cows perform yeoman service. An average dairy cow produces 15 tons of manure a year; this contains most of the nitrogen, phosphorus, and potassium from the feeds. The value of the manure depends upon the kinds of feed and bedding used, but in any case it is, when handled properly, an important source of the essential chemical elements and the organic matter required by the soil. In so far as legumes are included in the crop rotation of the farm as a source of dairy feed, the complementary value of the dairy enterprise in maintaining soil fertility is enhanced because of the nitrogen-fixing powers of those crops.

Reduced risks. Most income from farm enterprises is of a seasonal nature, depending upon crop harvests and market periods for livestock and livestock products. Dairy income, on the other hand, is continuous throughout the year, coming in the form of regular milk or cream checks. Thus, dairying tends to level out the farmer's income as well as place his eggs in more than one basket. Furthermore, dairying is influenced less by seasonal weather abnormalities than are crops, and the income tends to be more stable—because of the more dependable production, as well as the

greater stability of dairy prices. In periods of serious crop damage the dairy enterprise often affords an opportunity for farmers to salvage unmarketable or unharvestable crops as feed for the cows. During the drought of 1934 examples of this were legion in the stricken areas, where stunted fields of grain were used for pastures before they were completely ruined.

Reduced marketing costs. When dairy animals are able to utilize home-grown feeds or furnish supplies for the farm costs of transporting, buying, and selling these commodities are eliminated. In a sense, cows are kept to convert bulky grains and roughages into a less bulky human food, milk, which has a higher specific value. Thus, the cost of transporting and marketing farm produce is reduced when it is taken to market in the form of milk and cream.

Efficiency of the cow. The fundamental purpose of livestock on farms is the transformation of plant products into more desirable forms of food for human consumption. That type of livestock which can utilize the largest yielding crops and return the greatest proportion of the nutrients in the form of human food is the most efficient. The dairy cow has proved to be the most efficient farm animal. In the first place, cows excel in the use of roughage, and roughage, especially in the form of alfalfa, clover, or corn silage, yields larger amounts of digestible nutrients per acre than concentrated feeds such as oats, barley, or wheat. In the second place, the milk produced from 100 pounds of digestible nutrients contains more edible food solids than any other livestock product. When milk is converted into cheese and butter and the skim milk or whey is wasted; the cow as a producer of edible solids is surpassed by the pig; but even butter and cheese can be produced more efficiently than eggs, poultry, mutton, or beef, the principal rivals of milk among livestock products.

Income from dairying. Milk and dairy products brought to farmers a cash income of more than 4.4 billion dollars and a gross income (including value of milk products consumed in households on farms where produced) of 5.3 billion dollars in 1948. But, because of the changing value of money and the changing price level, the number of dollars received is of little consequence in measuring the true importance of dairy income as a part of the total farm income. When prices change not all commodity prices change at the same time or to the same extent; therefore, it is more useful to measure the proportion of the farm income that is derived from dairying. This point is well illustrated by the events of the last two decades. In 1929 the gross return from milk and dairy products at the farm was 2.32 billion dollars, in 1932 it was only 1.28 billion dollars, and by 1946 it rose again to 4.42 billion dollars. This was a drop of 45 per cent in three years and a rise of 245 per cent in the next 14 years. But during this same period the percentage of the total agricultural income obtained from milk increased from 19.5 per cent in 1929 to 23.6 per cent in 1932. This means that during the period of declining prices dairying took a relatively more important position with respect to farmers' income. After the succeeding rise the situation was reversed, and the gross farm income from

milk in 1946 was 16.3 per cent of the total agricultural income (exclusive of government payments).

The return from no other single crop or livestock product comprises so large a fraction of the agricultural income as does that from milk. The cash income from dairy products sold from farms, which is normally about 80 per cent of the gross income from milk, makes up one-fourth to one-third of the cash income from all livestock and livestock products. It is even more significant that the total income from the dairy enterprise, which includes the return from slaughtered dairy animals as well as from milk, accounts for one-fifth the agricultural income.

Dairy income depends for the most part upon the volume of milk produced and the prices received for it. The increased volume of milk production, together with the relative stability of dairy prices during the depression, accounts for the increased importance of the dairy income during that period. But the farmer's real wages are determined by the purchasing power of his income, which depends upon the prices of dairy products relative to the prices of other products, particularly those the farmers have to buy. In the past two decades, with the exception of 1945 and 1947, dairy prices have consistently remained high compared with the average for all products, and the purchasing power has also been higher, using 1909–14 for base comparisons, as is indicated in the following table.

INDEX NUMBERS OF PRICES RECEIVED AND PAID BY FARMERS (AUGUST 1909 TO JULY 1914 = 100) [1]

YEAR	PRICES RECEIVED		PRICES PAID BY FARMERS FOR COMMODITIES	RATIO OF PRICES RECEIVED TO PRICES PAID	
	Dairy Products	All Products		Dairy Products	All Products
1928	165	151	155	106	97
1929	164	149	154	106	97
1930	142	128	146	97	88
1931	111	90	126	88	71
1932	86	68	108	80	63
1933	87	72	108	81	67
1934	101	90	122	83	74
1935	111	109	125	89	87
1936	125	114	124	101	92
1937	130	122	131	99	93
1938	114	97	123	93	79
1939	110	95	121	91	79
1940	119	100	122	98	82
1941	139	124	131	106	95
1942	162	159	152	107	105
1943	193	192	167	116	115
1944	198	195	176	112	111
1945	197	202	180	109	112
1946	242	233	202	119	115
1947	269	278	246	109	113
1948	297	287	264	112	109

Since the base period 1909 to 1914, however, relative costs of production of different products have been altered considerably. The table re-

[1] *Agriculture Statistics*, U. S. Dept. Agr.

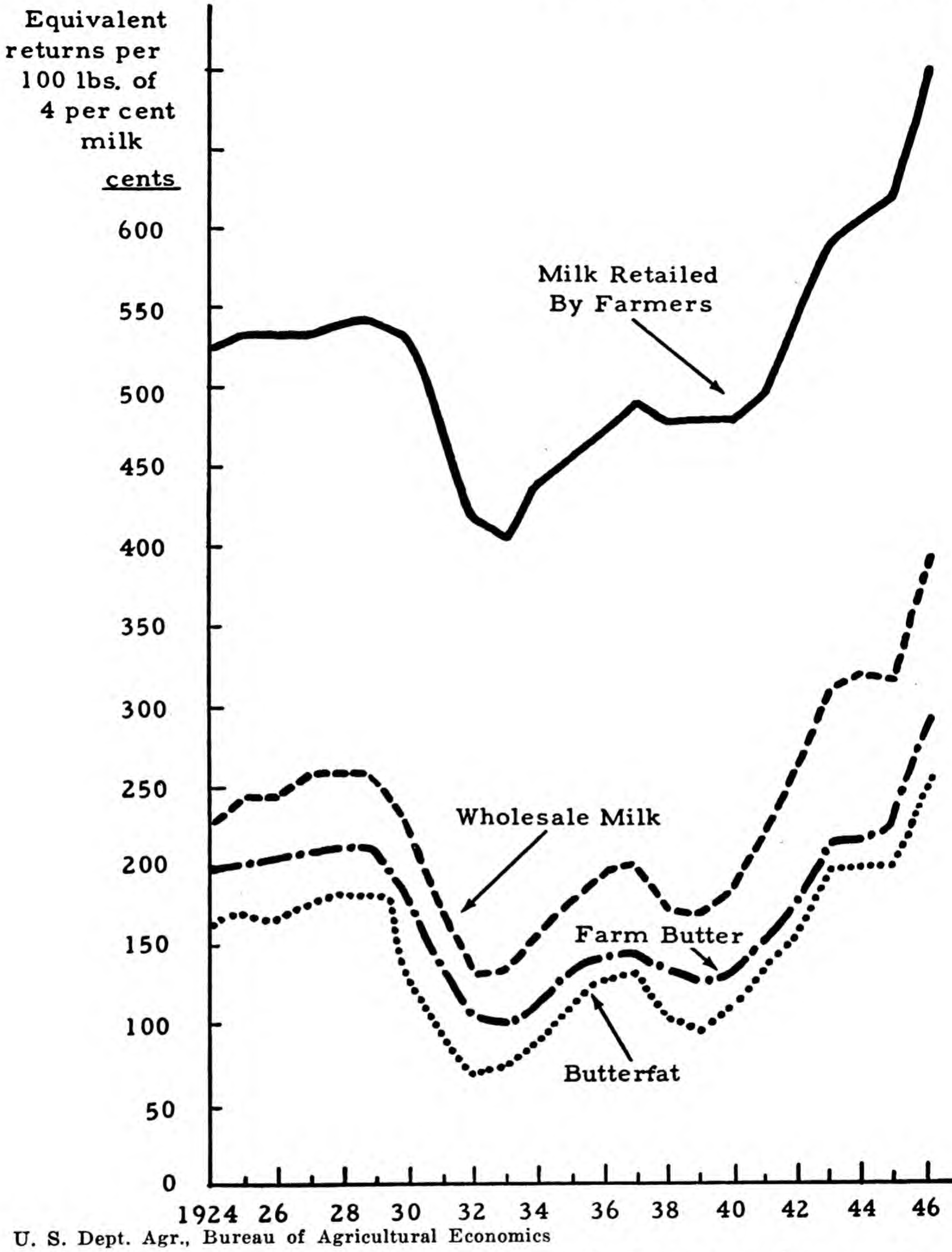


Fig. 5. Prices received by farmers of the U. S. for various dairy products, 1924 to 1946.

ferred to earlier showing changes in production per unit suggests that costs of production in dairying have not declined as rapidly as with some other types of agricultural production. This would mean that dairy prices would have to remain higher than other farm product prices based on 1909–1914 comparisons, if dairying is to be as remunerative as other farm enterprises.

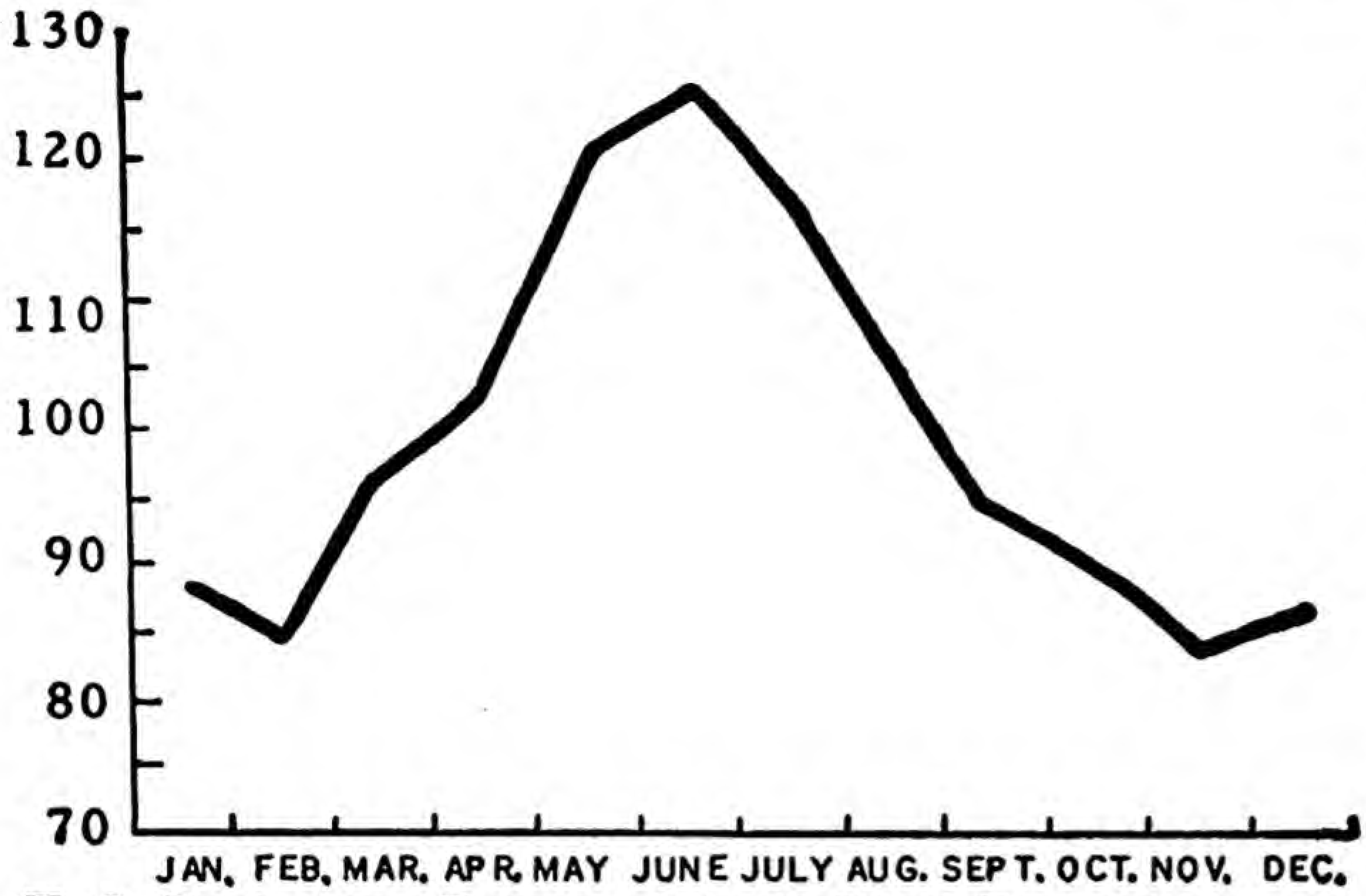
Because of the varying amounts of milk produced in different sections of the country and the different uses made of milk, the proportion of the total cash farm receipts derived from milk and dairy products varies a great deal between states. Vermont, representing the upper limit, receives more than 60 per cent of its agricultural income from milk, while North and South Carolina, at the lower extreme, each gets less than 5 per cent from this source. In general the Northeastern and North Central states rank the highest and the Southern states the lowest with reference to these proportions.

Because of the price differentials between various dairy products, the particular use for which milk is produced influences the return that is obtained. Figure 5 illustrates the price differentials existing from 1924 to 1946. Farm prices for milk usually decline as the distance from the city markets increases because of differences in quality requirements for the milk, transportation costs of the various products, and production facilities on the farms. For this reason the average price of milk is higher in those states containing large urban populations. When prices fluctuate the prices of milk going into the different products do not change simultaneously or to the same extent. During the price decline from 1929 to 1932 butterfat prices fell 60 per cent, whereas whole milk sold wholesale dropped 48 per cent. Surplus milk produced in the fluid milk areas during this period was converted into less perishable products, mostly butter. The butter market, therefore, bore the brunt of the price decline for the industry. During the upswing from 1932 to 1937, however, the price of butterfat increased 85 per cent while whole milk sold wholesale increased 54 per cent. These various reactions affected the price spread which normally exists between milk going into the different products, and, hence, between the areas producing them.

CHARACTERISTICS OF THE MILK SUPPLY

Just as prices differ between areas, the methods and practices of production that are associated with the different kinds of milk outlets vary. Distinctive characteristics of the milk supply which are not uniform in all areas include (1) seasonal fluctuations, (2) breeds of cattle, and (3) costs of production.

Seasonal fluctuations in supply. In addition to long-time changes in supply that are due to fluctuations in cow numbers and production per cow, the milk supply is subject to seasonal and short-time variations. Seasonal fluctuation follows a pattern that is illustrated in Figure 6. Allowing for the fewer days in February, the movement is distinctly upward from November and December to May and June, depending upon the section of the country. The peak of production occurs in the spring when pasture grass becomes available. During the hot months of July and August, when pastures decline, production falls off sharply until the low point is reached usually in October or November. In general, the quantity of milk produced is above average from April to August, and below average during the other seven months of the year.



U. S. Dept. Agr., Bureau of Agricultural Economics

Fig. 6. The seasonal index of milk production in the United States from 1930 to 1941 is shown in this graph.

Some modification of this seasonal supply pattern occurs in different production areas; the magnitude of the seasonal variation tends to increase as the distance from market increases. In areas supplying fluid milk markets the demand for fresh milk is relatively constant throughout the year, and, since whole milk cannot be carried over from periods of surplus to times of shortage, the farmers are encouraged to produce a uniform quantity of milk the year around. Producers take advantage of price premiums offered for uniform supplies by having their cows freshen at different periods and by adjusting their feeding practices to secure a steady milk flow. These farmers generally use a high proportion of concentrated feeds and silage with relatively little pasture, so that such adjustments are not hard to make. Outlying producers who ship milk to creameries, condenseries, and cheese factories rely more upon pasture feeding, and the good pasture months of May and June are accompanied by the highest production. During July and August pastures tend to become dry and provide much less grass. These farmers avoid having cows freshen in late summer and fall months, so production declines until the silos are opened and more cows freshen. In these areas production costs tend to be appreciably lower during the spring and summer months, and the savings obtained by means of a heavy seasonal production are justified because the butter and cheese can be stored for consumption in periods of deficient milk supply.

Short-time changes in milk supply. Short-time changes in milk supply are relatively insignificant. They are seldom sufficiently great to have drastic effects upon the milk market, and then only in localized territories. While a single cow's milk production may be reduced noticeably from one day to the next, the total production of a number of cows does not change materially over a short period. Most abrupt changes in market supply are caused by severe weather resulting in floods, or in muddy or snow-blocked roads which interfere with the regular transportation of milk to market. In some cases milk strikes and similar disturbances have the same effect on the supply, but enough milk to fill the most urgent needs of a market is always made available.

Distribution of breeds of cattle. Another factor exerting a characteristic effect upon the milk supply of any territory is the breed of cattle

which predominates in the producing area. Differences in production per cow and butterfat test of the milk are associated with the proportions of the breeds in the herds. Breed preferences appear to depend largely on the climatic, pasturage, and feed conditions, and on the purpose for which the milk is used. The high-producing, low-testing cows of Holstein extraction are most prevalent in the areas supplying market milk. Over half the cows in the North Atlantic states are of the Holstein type, and the majority of the Ayrshires are located in this territory. The high-testing Jerseys and Guernseys are more prevalent in the East North Central states in the butter and cheese areas, but the proportion of Jerseys is highest in the South. In the butter-producing areas of the West North Central states Shorthorns and other dual-purpose breeds are more prevalent.

A definite relationship exists between the size of the herds and the breed preferences of the farmers. Most of the one-cow farms have cows of Jersey extraction, and this breed prevails in the herds containing less than five cows. Holsteins, on the other hand, are found in greatest proportions in the large herds. Cows of the Shorthorn type find their greatest use in middle-sized herds of from six to ten cows.

Cost of production. The cost of milk production is by no means a fixed or determinable quantity because of the wide range of circumstances under which milk is produced. Costs incurred by producers in the North Atlantic states are not comparable with those in the North Central states. The North Atlantic producers buy three-quarters of the grain and concentrates, which they feed in large proportions rather than transport bulky roughages. They have to conform to stricter sanitary regulations, pay higher wages, and contend with relatively greater costs than do the farmers in the North Central states, who buy only one-fifth of their concentrates and produce milk more as a side line. Neither are the costs between individual farms any more similar than are the efficiencies and abilities of the farmers or the contours and productive capacities of the lands. A cost analysis requires that so many assumptions and arbitrary calculations be made regarding such items as rates of interest and wages, values of manure and skim milk, and rents of crop and pasture lands that no accounting methods have yet been devised by which the cost of producing a hundredweight of milk in any area can be determined with any high degree of accuracy. Cost estimates based upon uniform accounting methods from year to year are, nevertheless, useful and reliable to indicate the direction and general magnitude of change from one period to another.

Despite difficulties of determining the exact production costs, there is ample reason to believe that the costs of milk production are higher than need be. That poor, neglected pasture lands deficient in soil fertility are used is a matter of common knowledge throughout the country. The fact that a large number of "boarder" cows is causing the average milk production per cow to be only a fraction of what it might be is also well known. These conditions, together with the existence of large surpluses in the Eastern milksheds where it is uneconomical to produce milk except for immediate fluid consumption, are some of the factors observed which

lead to the conclusion that there is much room for the improvement of production efficiency in this country.

Quality of the milk supply. No change in the milk supply has been more manifest than the improvement in quality. Through continued efforts of health authorities and progressive dairy leaders, market milk supplies are subjected to rigid specifications and requirements that have brought about better housing for the animals and more sanitary conditions for handling the milk. With the almost universal introduction of pasteurization supplementing these other quality improvements, infant mortality and morbidity and epidemics due to milk-borne diseases have been reduced to a minimum. Improved transportation and refrigeration facilities have brought larger amounts of clean, high quality milk within reach of the consumers. Quality improvement campaigns conducted among the cream producers and the trend toward whole milk creameries have raised the average quality of milk going into other dairy products. Disease eradication programs have reduced the number of animals infected with tuberculosis to less than 1 per cent and have made progress toward the control of Bang's disease in dairy herds. The betterment of the milk supply thus attained has fostered consumers' confidence in milk as a food, and has stimulated the demand for all dairy products.

Chapter 3

MILK CONSUMPTION[1]

MILK DISPOSAL BY FARMERS

SEVERAL WAYS OF DISPOSING OF HIS MILK ARE OPEN TO EVERY FARMER. The first choice which confronts him is one of selling the milk or keeping it himself; or, rather, as is the case with most farmers, it is a question of how much should be kept at home and how much should be sold. If the decision is made to keep the milk at home, it may be used as whole milk or cream in the farm household or be made into farm butter and cheese, and either whole milk or skim milk may be fed to calves and other livestock. If milk is to be sold, the farmer must then decide whether it is to be sold as whole milk or cream. These decisions are made after the farmer takes into account the amount of milk he has available, the markets within his reach, the facilities he has for handling the milk on the farm, and the returns which he can obtain from it in each of the alternative uses. These returns are, of course, dependent upon the market prices for milk and cream and the utility he has for either whole milk or skim milk on the farm.

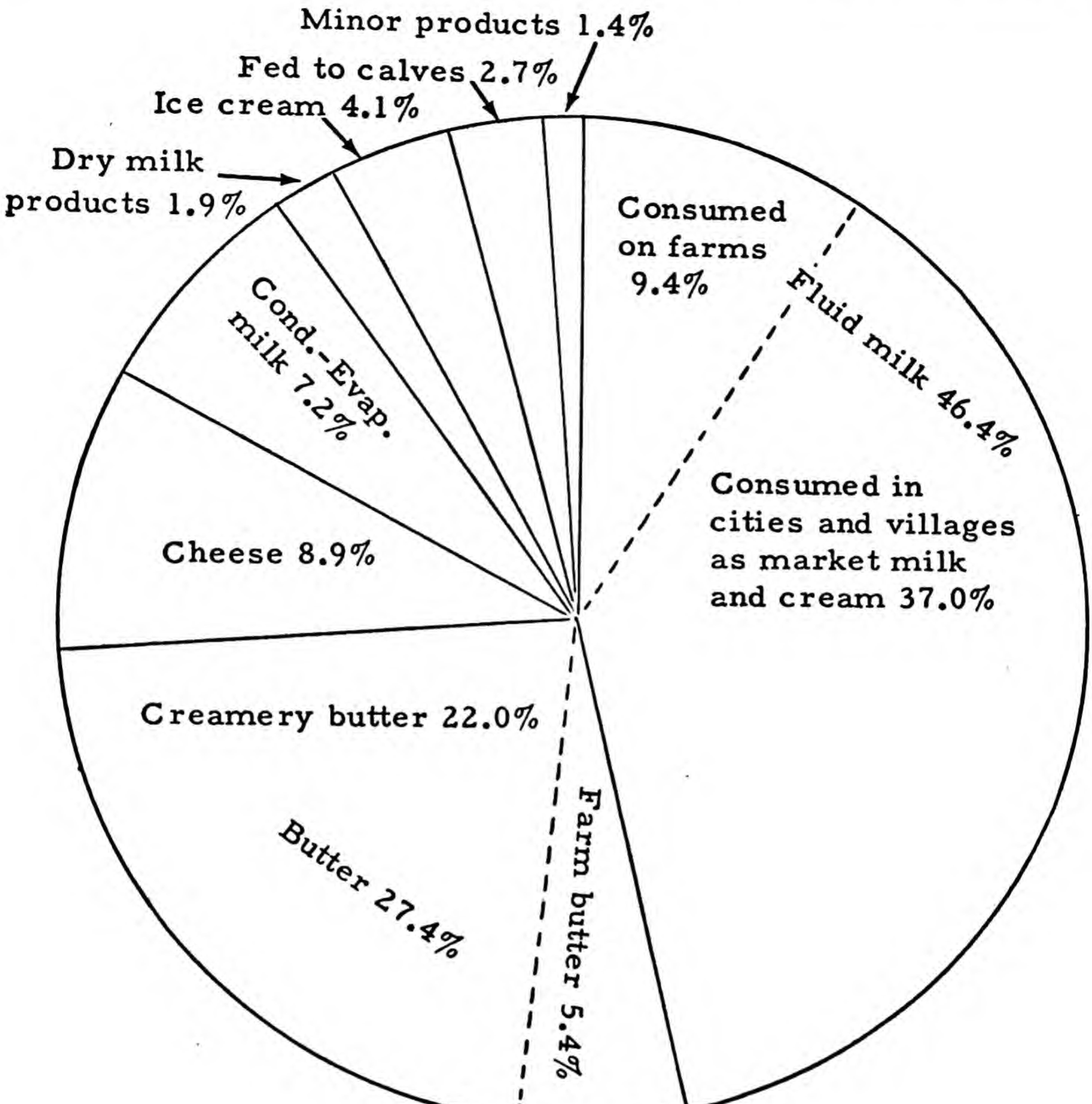
In this day of specialization little milk processing is done on the farm, and therefore all farmers, taken collectively, send four-fifths of their production to market as whole milk or cream. Well over half the milk is just strained and cooled and sold at wholesale prices to milk dealers, cheese factories, condenseries, or whole-milk creameries. One-fifth is separated on the farm and the cream is sent to milk dealers or creameries. Nearly 5 per cent of the milk is bottled on the farm and distributed to consumers by the farmer producers themselves. The table on page 34 shows the quantity of milk handled in these different ways in 1947.

USE OF MILK BY URBAN CONSUMERS

Farmers determine the ultimate use of only that quarter of the milk which they keep at home; the use of the other three-quarters is governed by consumers' preferences for the different dairy products that appear on the market. Manufacturers and distributors of dairy products serve as middlemen, taking the raw materials from the farm and making and distributing the products which consumers desire. It is part of their function to allocate milk to its best uses, but their judgment in doing this is influenced by the consumers' demands, which in turn determine the prices that can be charged and the profitableness of different dairy manufacturing enterprises.

By far the largest portion of milk produced in 1947 was consumed as fluid milk or cream. Next in importance was the amount used to make

[1] Harry C. Trelogan, Ph.D., Assistant to the Administrator Agricultural Research Administration, U. S. Dept. of Agr., contributed this chapter.



124,330

Fig. 7. Disposition of milk among its various uses, 1945.

FARMERS' METHODS OF DISPOSING OF MILK IN 1947 [1]

Use	Million Pounds	Per Cent
Used on the farm		
Whole milk or cream	12,295	10.3
Farm churned butter *	5,302	4.5
Fed to calves	3,228	2.7
Sold from the farm		
As farm butter *	966	0.8
Retailed as milk and cream	5,178	4.4
Wholesale cream deliveries *	20,969	17.6
Wholesale milk deliveries	71,127	59.7
Total	119,065	100.0

* Expressed as whole milk equivalent.

[1] Bureau of Agricultural Economics, U. S. Dept. Agr.

creamery and farm butter. Prior to the last war the quantity of milk separated and churned to make butter closely rivaled the quantity used for fluid milk and fluid cream. While both farm and creamery butter production have declined substantially, the prospects are for some recovery in creamery butter production but a continuation of the downward trend in farm butter.

Relatively less important products have absorbed the rest of the milk going to market. These include cheese, ice cream, and dried, condensed and evaporated milks, which together take less than one-fourth of the total milk production. The item for ice cream shown in the classification of milk uses presented in Figure 7 includes other frozen dairy foods, such as sherbets and iced milks, but it is somewhat understated because it does not include the milk equivalent of other dairy products, such as butter and condensed milk, that are frequently used to make ice cream. This classification takes into account only the chief products of milk

TOTAL SUPPLY AND UTILIZATION OF MILK IN THE U. S., 1937–1941 AVERAGE, AND 1942 TO 1947[1]
(Million Pounds)

	1937–1941 Average	1942	1943	1944	1945	1946	1947
Milk production							
By cows on farms	107,855	118,884	117,785	117,992	121,504	119,713	119,065
Total [1]	110,681	121,710	120,611	120,818	124,330	122,539	121,891
Utilization (milk equivalent)							
Manufactured in plants							
Creamery butter							
Total	36,142	35,938	34,460	30,620	28,065	24,145	27,440
From whey cream	533	775	698	713	780	772	826
Net	35,609	35,163	33,762	29,907	27,285	23,373	26,614
Cheese							
American	5,976	9,247	7,743	8,090	8,777	8,058	9.386
Other	1,671	1,874	2,179	2,044	2,346	2,894	2,341
Canned milk							
Evaporated	5,096	7,592	6,594	7,384	8,147	6,567	6,899
Sweetened condensed	135	147	278	330	339	269	389
Bulk condensed milk							
Unsweetened	298	307	249	289	310	237	424
Sweetened	133	163	145	138	166	151	179
Dry milk products							
Dry whole milk	204	474	1,052	1,355	1,650	1,421	1,250
Other [2]	54	94	196	514	720	552	518
Ice cream							
Total	4,671	6,795	5,376*	5,557*	6,057*	9,703	8,840*
Fat from other products [3]	978	1,457	826	859	926	1,507	1,346
Net—from milk and cream	3,693	5,338	4,550*	4,698*	5,131*	8,196	7,494
Total factory products [4]	52,869	60,399	56,748	54,749	54,871	51,718	55,494
Used for farm butter	8,694	7,365	6,851	6,608	6,755	6,630	6,268
Consumed as milk or cream							
In cities and villages	33,229	37,650	41,000	43,000	46,000	47,000	45,000
On farms where produced	12,031	11,856	11,615	11,685	11,671	12,318	12,295
Fed to calves	2,932	3,294	3,276	3,270	3,335	3,255	3,228
To balance [5]	927	1,146	1,121	1,506	1,698	1,618	394

[1] Includes an allowance of 2,826 million pounds for milk produced by cows not on farms, the same as in 1930 when information on this item was last obtained. [2] Includes dry cream, malted milk, dry part skim milk and dry ice cream mix. [3] Milk equivalent of butter and condensed milk used in ice cream. [4] Includes net milk equivalents on butter and ice cream to avoid double counting of fat reused in making a second dairy product. [5] Residual, including miscellaneous minor uses; net imports, exports and year-end carry-over of milk and cream, as well as any inaccuracies of independently determined use estimates.
* Includes milk sherbets and ice milk.

[1] Bureau of Agricultural Economics, U. S. Dept. Agr.

which have the common characteristic of containing butterfat, milk's most valuable constituent. The by-product uses of milk must necessarily be left for another classification.

In view of the rather sharp changes that have occurred in milk production and utilization in recent years, a more detailed breakdown of the data is shown in the table on page 35.

FOREIGN TRADE IN DAIRY PRODUCTS

Ordinarily very little of the milk supply is used for dairy products going into export trade, and only small quantities of dairy products are imported into this country. For all practical purposes the small amount of foreign trade in dairy products is balanced with the imports of cheese, consisting mainly of types not produced extensively in this country, being offset by exports of condensed and evaporated milk. War and postwar relief feeding caused our dairy exports to far exceed imports for several years, but a distinct reversion to prewar conditions is occurring. Recent exports have consisted mainly of nonfat dry milk solids made from skim milk, the production of which was greatly expanded for war purposes. Ultimately most of this production which is unlikely to contract to prewar levels will have to be absorbed in domestic skim-milk outlets.

The principal reason for the small amount of dairy imports is the high tariffs that apply to milk and all milk products. These high tariffs are effective in excluding most foreign dairy products from our markets except when extreme milk shortages lead to abnormally high prices for these products, as occurred following the drought of 1934. Ordinarily, domestic prices for dairy products are not raised above the world prices to the full extent of the tariff. For instance, during the five-year period from 1932 to 1936 the average New York 92 score butter price exceeded the average London price for butter of similar quality by 8.23 cents per pound, while the tariff was 14 cents throughout this period. The monthly average of New York prices ranged from 1.20 cents above the London price to 17.85 cents above, and the tariff was fully effective during only seven of the 60 months.

CONSUMPTION OF DAIRY PRODUCTS

As was indicated in the preceding chapter, the total demand for milk is derived from the demands for particular dairy products on the market. Some idea of the relative importance of these products and their influence upon total demand for milk can be obtained from a survey of their consumption. Per capita consumption of each of the major dairy products for the past two decades, indicated in the table below, is briefly discussed in the following paragraphs.

To compute total per capita consumption of milk in all dairy products it is necessary to convert the per capita consumption of each product into its milk equivalent and combine the milk equivalents. To make this conversion to milk equivalent—that is, the amount of milk required for each

ANNUAL PER CAPITA CONSUMPTION OF DAIRY PRODUCTS IN CONTINENTAL UNITED STATES, 1925 TO 1946 [1]
(Pounds)

Year	Fluid Milk and Cream	Condensed and Evaporated Milk	Dry Whole Milk	Butter	Cheese	Ice Cream	Nonfat Dry Milk Solids for Human Consumption
1925	353.5	11.7	.07	17.7	4.6	9.4	—
1926	354.4	11.8	.10	17.5	4.7	9.2	—
1927	353.3	11.6	.10	17.5	4.4	9.4	—
1928	353.9	12.2	.07	17.2	4.4	9.4	—
1929	356.3	13.6	.11	17.4	4.6	10.0	—
1930	350.9	13.5	.10	17.2	4.6	9.1	—
1931	348.4	13.3	.06	18.0	4.4	7.8	—
1932	350.3	13.9	.07	18.1	4.3	5.8	—
1933	348.8	13.7	.09	17.8	4.5	5.5	—
1934	333.4	14.9	.12	18.2	4.8	6.6	—
1935	335.4	16.1	.15	17.1	5.2	7.3	1.6
1936	340.6	15.8	.15	16.4	5.3	8.9	1.8
1937	342.3	16.6	.11	16.4	5.5	10.2 *	1.9
1938	338.3	17.1	.12	16.4	5.8	10.1	2.1
1939	344.0	17.7	.13	17.3	5.9	10.9	2.2
1940	343.1	19.2	.14	16.9	6.0	11.2	2.2
1941	350.6	18.3	.17	15.9	6.0	13.5	2.4
1942	372.0	18.3	.19	15.7	6.3	15.8	2.3
1943	393.0	18.6	.38	11.7	5.0	12.2	2.0
1944	411.0	16.1	.35	11.9	4.9	13.2	1.7
1945	433.0	18.3	.30	10.8	5.9	13.8	2.0
1946 **	425.0	18.8	.51	10.2	6.9	23.1	3.4

* Since 1937, includes production of small retailers and counter freezers.
** Preliminary

unit of factory production—the following conversion factors are used: butter, 20.3 pounds; cheese, 10.0 pounds; condensed and evaporated milk, 2.2 pounds; and ice cream 2.5 pounds. The ice cream factor represents the net normal use of milk and excludes milk duplicated in butter and condensed milk subsequently used for ice cream manufacture. The gross normal factor is 3.2 pounds of milk per pound of ice cream. By this method the 1946 per capita consumption of milk in all its various forms can be roughly estimated as 804 pounds or 93.5 gallons as shown by the following table.

Product in Pounds	Per Capita Consumption in 1946		Conversion Figure		Milk Equivalent in Pounds
Fluid milk and cream	425.0	×	1.0	=	425.00
Condensed and evaporated milk	18.8	×	2.2	=	41.36
Dry whole milk	.5	×	7.6	=	3.88
Butter	10.2	×	20.3	=	207.06
Cheese	6.9	×	10.0	=	69.00
Ice Cream	23.1	×	2.5	=	57.75
Total pounds of milk		×		=	804.05
Gallons of milk (804.05 ÷ 8.6)				=	93.5

[1] Bureau of Agricultural Economics, U. S. Dept. Agr.

MARKET MILK

Market-milk consumption [1] is estimated from the milk and cream used in cities and villages as reported by Federal milk marketing administrators, local boards of health, and other regulatory or distributing agencies. The demand for market milk is believed to be inelastic since its consumption does not ordinarily change a great amount from year to year and the demand does not usually rise or fall very much with changing economic conditions. Prior to 1929, consumption of market milk experienced a slow but steady rise to a peak of 356 pounds per capita. Since that time there have been two notable changes in fluid milk consumption that have been of substantial magnitude. First, there was a decline in consumption during the depression in the early 1930's, reaching a low point of 333 pounds in 1934. Explanation of this decrease may be found in the relative stability of market-milk prices during the time that consumer incomes were falling sharply in most urban centers. Part of this decline can be attributed to the decided reduction in cream consumption accompanying lowered incomes, and part to the tendency for people to substitute cheaper evaporated milk for market milk. The latter tendency was especially marked in the Southern states, where daily per capita consumption of market milk is distinctly smaller (in the neighborhood of 0.6 pints) than in the North Atlantic states (where it approximates 1.0 pint). Following 1934, milk consumption showed a slow, steady increase which did not reach the 1929 level until 1942. In 1942 and each of the three following war years fluid milk consumption experienced a rapid substantial increase. This may be attributed for the most part to higher incomes of those years. It was partially the result of rationing restrictions and shortages of food that were relatively more severe with other food products, including dairy products, than with milk. As rationing and price controls were relaxed after 1945 milk consumption started to decline but with the continuation of high incomes, it remained well above prewar levels.

It is a significant fact that children are much heavier consumers of whole milk than adults, because they drink greater quantities of it and because more of the children are regular milk drinkers. Competition from such products as tomato juice, citrus fruit juices, soft drinks and beer has a greater influence upon adult milk consumption. Nevertheless, it is apparent that the war, through expansion of incomes and creation of different food habits, has had a decided stimulating effect upon fluid milk consumption, particularly among adolescents and adults.

BUTTER

Fluctuations in butter consumption tend to accompany changes in production because total butter consumption is closely dependent upon

[1] Consumption, as the term is used here, refers to the physical amount of a commodity that is utilized by people for the satisfaction of their wants. Demand, on the other hand, refers to the schedule of the respective quantities of a commodity which people will buy at all possible prices. The total consumption at any particular time depends upon the price of the commodity and the existing demand.

domestic production. Since butter is the final claimant of milk not used for other dairy products, its production increased during the depression when the milk supply was large but the demand for market milk and cream low. Conversely, its production declined drastically in the war years when the demand for market milk and for other dairy products was exceptionally high. Consequently, butter consumption was increased in the depression, reaching its highest point of 18.1 pounds per capita in 1932 and declined in the war years reaching its lowest point of 10.2 pounds per capita in 1946. This direct relationship between consumption and domestic production of butter is attributable in large measure to restrictions on foreign trade in butter. In fact 1935, with imports of 22 million pounds of butter, was the only year of the last 20 years in which butter imports exceeded 1 per cent of domestic production. And, in only three years—1935, 1937, and 1941—did imports have a significant effect upon per capita consumption.

Consumption of butter is higher among people who receive large incomes. This is largely due to the substitution of oleomargarine for butter by people in the lower income brackets. Oleomargarine sells for a lower price than butter and tends to be used more when butter prices rise as the result of low production. From 1934 to 1936, when creamery butter production fell 84 million pounds, oleomargarine production increased 128 million pounds, or from 15.5 per cent of the creamery butter production to 24.2 per cent. Conversely, from 1929 to 1932, when butter production increased 140 million pounds, oleomargarine production fell 158 million pounds. Thus, these two products tend to be used interchangeably. This gives butter an elastic demand, a condition that tends to cushion the shock of price changes for the entire dairy industry.

CHEESE

Cheese, an animal protein food that is substitutable for meat, is less popular in the United States, where meat is more plentiful, than it is in European countries. With the influx of European immigrants into this country, cheese making and cheese consumption gradually increased until it reached about 4.5 pounds per capita in 1924. It remained quite close to that point for ten years. Thereafter, the development of process cheeses and cheese spreads caused consumption to rise gradually during the succeeding eight years, reaching a peak of 6.3 pounds per capita in 1942. The use of these new forms of cheese which are adapted to convenient packaging and modern consumption habits has been promoted by strenuous merchandising campaigns that contributed toward the substantial uptrend of consumption.

During the years of World War II cheese consumption was definitely restricted, despite a marked expansion in production, to permit greater quantities of American Cheddar cheese to be shipped overseas for war purposes. With the cessation of war and the relaxation of rationing restrictions, cheese consumption jumped very rapidly, reaching new high levels in 1946 and 1947. This development was made possible by the continua-

tion of high production rates achieved during the war, and consumption was aided and abetted by high consumer incomes, together with relative shortages and high prices for meat and other protein foods. Cheese consumption, like butter, is quite responsive to price changes and is therefore usually higher among families receiving larger incomes.

Another factor contributing toward recent increases in cheese consumption has been the development of a variety of new types of natural cheeses closely simulating imported cheeses, the consumption of which was virtually eliminated during war years. Among the varieties of soft cheeses that have been developed are a number that are distinctly original in character.

CONDENSED AND EVAPORATED MILK

The great bulk of milk in this category is consumed in the form of evaporated milk. Condensed-milk consumption has been on the down trend, while evaporated-milk consumption has been increasing rapidly and steadily so that the net change for these concentrated milk products is upward. The war interfered with these trend changes by stimulating condensed-milk consumption somewhat and by causing evaporated milk consumption to be reduced temporarily through rationing restrictions even though production was expanded materially. With the end of the war, the trend changes that were apparent prior to its outbreak seem to have been resumed.

The superior keeping qualities and cheapness of evaporated milk, when compared with market milk and cream, make it most popular in the Southern states and among families having low income, especially those that do not have access to refrigeration facilities. It is one dairy product for which consumption is greater among low-income families than high-income families.

Because of the fact that evaporated milk is sterile and still retains most of the nutritive value of fluid milk, it has achieved the position of being almost indispensable in the feeding of infants in this country.

ICE CREAM

Of all dairy products, ice cream consumption is most sensitive to changes in consumer income and general industrial prosperity. Ice cream consumption, which had increased until 1929, was reduced sharply during the depression but it recovered rapidly thereafter. With the stimulation of industrial activity that accompanied the outbreak of war, ice cream consumption reached new high levels far above any preceding periods. In 1942, the consumption reached 15.8 pounds per capita before it was sharply contracted as a result of wartime restrictions on production. With the relaxation of these restrictions and very high postwar incomes, ice cream consumption in 1946 reached a new high peak of 23.1 pounds per capita.

These data pertain to commercially produced ice cream. They do not include per capita consumption of homemade ice cream which has in-

creased markedly with the introduction of mechanical refrigeration in many homes. The increased accessibility of refrigeration facilities adapted to the convenient distribution of frozen foods, as well as the production of frozen foods in the homes, has caused consumers to accept ice cream as a good, wholesome food rather than a luxury. This would indicate that, even though some decline has occurred in the consumption of commercially produced ice cream since the peak was reached in 1946, a higher proportion of milk solids is likely to be consumed in frozen form in the future.

MINOR DAIRY PRODUCTS

A market for powdered whole milk and cream is primarily an industrial market where these products are incorporated in other foods such as confectioneries and bakery goods. Even though the exigencies of war caused a stimulation in the consumption of powdered whole milk, there is little reason to expect a significant rise in the consumption of these products.

Although the consumption of malted milk, which was declining prior to the last war, has been stimulated significantly in recent years, relatively little milk is used in its preparation. With a conversion factor of only 2.6 pounds of whole milk for each pound of malted milk, it is evident that malted milk is not an important factor influencing the demand for milk.

One of the minor dairy products that has experienced a significant increase in consumption that appears to be of a durable nature is ice cream mix prepared in either fluid or dried form. The development of mechanical refrigeration for homes, and counter freezers for making ice cream in stores and restaurants has led to a large demand for ready-made ice cream mixes and prepared ice cream powders that contain milk and cream in concentrated form.

Another group of minor dairy products that experienced a substantial rise in production is made up of milk base infant foods. These products in both fluid and dried form represent various degrees of modification of the basic ingredient—milk—in accordance with formulas designed to yield convenient, desirable products especially adapted to infant feeding.

BY-PRODUCTS OF MILK

The principal by-products of milk are obtained from skim milk, buttermilk and whey—the parts of milk remaining after separation, churning and cheese making, respectively. Demand for milk by-products does not constitute a major factor contributing to the basic demand for whole milk because these products remaining from milk processing are not completely utilized. In 1934, there were more than 38 billion pounds of skim milk available on farms and in factories where milk was separated but not over seven billion pounds of it was used in the manufacture of skim-milk products. A substantial portion of it was used for feeding purposes on farms but even so there was much skim milk unutilized and wasted. The same was true with respect to whey and buttermilk. The consumption of

milk by-products has been definitely on the upturn since that time and in 1945 well over 13 billion pounds of skim milk was used in the commercial manufacture of dairy by-products. This utilization was greatly stimulated by the developments of the war and also by the postwar demands for relief feeding abroad. Even though this stimulation will subside, it is apparent that more complete utilization of the milk by-products may be anticipated in the future. Continued research and education concerning the value of these available by-products both for nutritional and industrial purposes, which led to their increased use, will be a distinct benefit to the dairy farmer as it supplements the demand for his milk.

A classification of products which are made from milk in this country appears in the following table. This arrangement is manifestly incomplete in detail because numerous products are included under general headings. There are, for instance, over 200 varieties of cheese, but only the main varieties made here are listed. No attempt is made to list the myriad of products, ranging from pool balls and fountain pens to glues and face powders, that are made from casein. Nor can the classification attempt to cover the vast number of food products, such as bakery products and confectioneries, which contain milk constituents. Nevertheless, some conception of the wide variety of milk uses which contribute to the total demand for milk can be obtained.

Scientists are constantly finding new uses for milk constituents, and practical methods for isolating desired components from this very complex chemical substance on a commercial scale are being continually devised. Accordingly, the list of products prepared from milk is growing.

CLASSIFICATION OF MILK PRODUCTS

Chief products:

Market milk

- Raw milk
- Certified milk
- Pasteurized milk
- Vitamin D milk
- Homogenized milk
- Chocolate milk
- Acidophilus milk
- Bulgarian buttermilk

Market cream

- Coffee cream
- Whipping cream
- Sour cream
- Sterilized cream

Butter

- Sweet-cream butter
- Sour-cream butter
- Renovated butter
- Sweet (unsalted) butter
- Ripened-cream butter

Cheese

- Cheddar cheese
- Cream cheese
- Process cheese
- Swiss cheese
- Blue (Roquefort) cheese
- Limburger cheese
- Brick cheese
- Camembert cheese
- Italian varieties
- Cheese spreads

CLASSIFICATION OF MILK PRODUCTS—*Continued*

Chief products:

Concentrated products
- Evaporated milk
- Condensed milk
  - Plain condensed
  - Sweetened condensed

Dried products
- Powderd whole milk
- Powdered cream
- Malted milk

Ice cream

Ice cream mix

Frozen cream

Plastic cream

Butteroil

By-products:

Skim milk
- Nonfat dry-milk solids
- Dried skim milk
- Condensed skim milk
- Evaporated skim milk
- Cottage cheese
- Pot cheese
- Baker's cheese
- Skim-milk American cheese
- Chocolate milk
- Concentrated sour skim milk
- Dry-milk compounds
- Infant foods
- Prepared foods
- Casein
  - Plastics
  - Adhesives
  - Spreaders
  - Coatings
  - Casein sols
  - Textiles

Buttermilk
- Dried buttermilk
- Semisolid buttermilk
- Prepared foods

Whey
- Dried whey
- Whey cheese
- Whey butter
- Albumin
- Lactose (milk sugar)
- Lactic acid
- Medicinal preparations

Chapter 4

ECONOMICS OF MARKET MILK

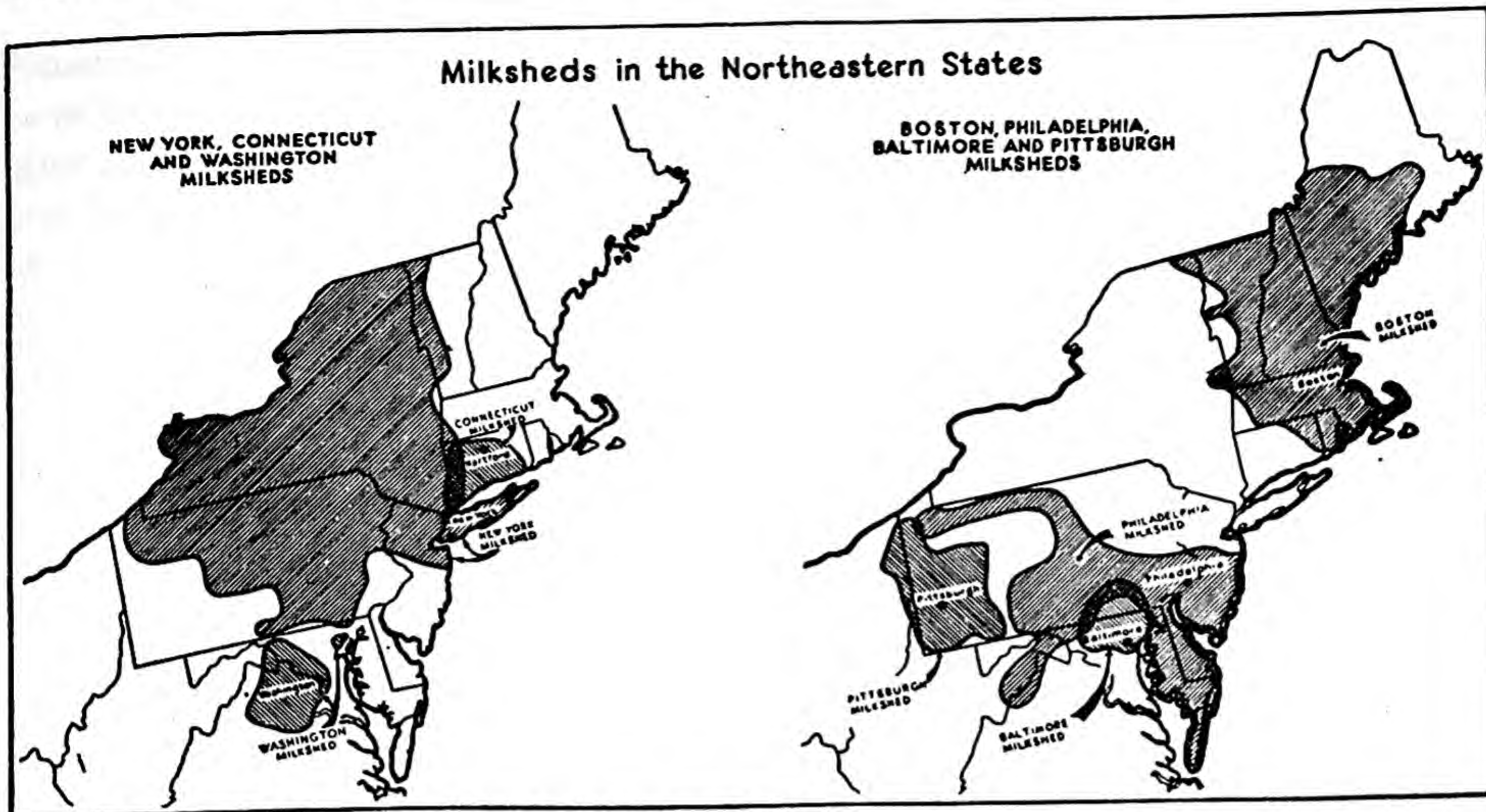
Economic production is defined as any activity that satisfies a human want. It embraces transportation, manufacturing, distribution, and selling no less than it does the primary creation of raw materials. Consequently, production of dairy products is not complete until the consumers receive them in the desired form at the proper time and place. Several separate and distinct industries have been developed to perform these functions in the dairy field. The most important of these industries, from both a volume and financial standpoint, is the market-milk business, which has for its purpose the preparation and distribution of whole milk and related products, principally market cream. The market-milk industry is characterized by processing plants located in every city throughout the country. To these plants the raw, whole milk is brought for pasteurization and bottling, and from them the milk is delivered to stores, hotels, restaurants, hospitals, and homes every day. While the milk distributing systems of no two cities are identical because each system has been adapted to the particular needs of the community in which it is located, certain economic problems are common to all of them, and it is the purpose of this discussion to treat these problems in a general way without attempting to analyze the circumstances surrounding any specific market.

SUPPLY AREA

Market milk is usually produced in the territory immediately surrounding the city in which it is consumed in what is known as the milkshed. Since the milkshed embraces the area from which milk flows to the city, its scope depends upon the size of the city, the per capita consumption of milk within the city, and the intensity of milk production in the adjacent farming area. Wide differences in the sizes of existing milksheds attributable to the latter factor can be observed. For example, the Twin Cities (Minneapolis and St. Paul), located in an area of dense cow population, are able to secure all the milk needed for that market within a radius of 40 miles, while St. Louis, a city with fairly comparable milk consumption and similar surroundings, must reach out as far as 150 miles in order to obtain its milk supply.

Under ideal conditions, with a city located in the center of a uniformly good farming area and with transportation available in all directions, the milkshed might be expected to be circular in shape. The Twin City milkshed represents a rather close approximation to such a situation, it being roughly circular but distorted somewhat as it extends out along established transportation routes. But since most large cities are located along water-

[1] Harry C. Trelogan, Ph.D., Assistant to the Administrator, Agricultural Research Administration, U. S. Dept. of Agr., contributed this chapter.



Dairy Section, Farm Credit Administration, circa 1935

Fig. 8. Large milksheds overlap and take peculiar shapes in heavily populated areas.

fronts the milksheds necessarily extend out in some directions more than in others. For instance, the Baltimore milkshed is largely north and west of the city (see Fig. 8). This condition, together with the effects of rivers, mountains, and transportation routes, tends to give most milksheds an amoebic shape, with the boundaries enclosing the nearest accessible good farming territory.

While the boundaries of a milkshed usually follow a rather natural course according to the farming conditions, they are often definitely specified and limited by municipal health authorities who designate areas within which they will inspect and approve milk-producing farms. For this reason, milksheds sometimes take a little different size and shape than they would if they were determined by economic forces under conditions of free competition. In some areas, especially in the Northeastern section of the country, the milksheds are further complicated by the proximity of the cities. Thus, there is overlapping, as in the case of the New York and Philadelphia milksheds, and also complete circumvention, as in the Boston milkshed, which surrounds the Lawrence, Lowell, Springfield, and Worchester supply areas. In situations like the latter the larger metropolitan market is called the primary market, and the smaller cities are called secondary markets.

Although the boundaries of a milkshed may be specified by health authorities, the outer limits of the area actually shipping milk to the city market do not always coincide with them. The milk supply from the entire milkshed is needed by the market only during the seasons of short production. During the spring season of flush production a much smaller area supplies sufficient milk to meet the needs for market milk and cream. When the specified milkshed is extended to include sufficient area to

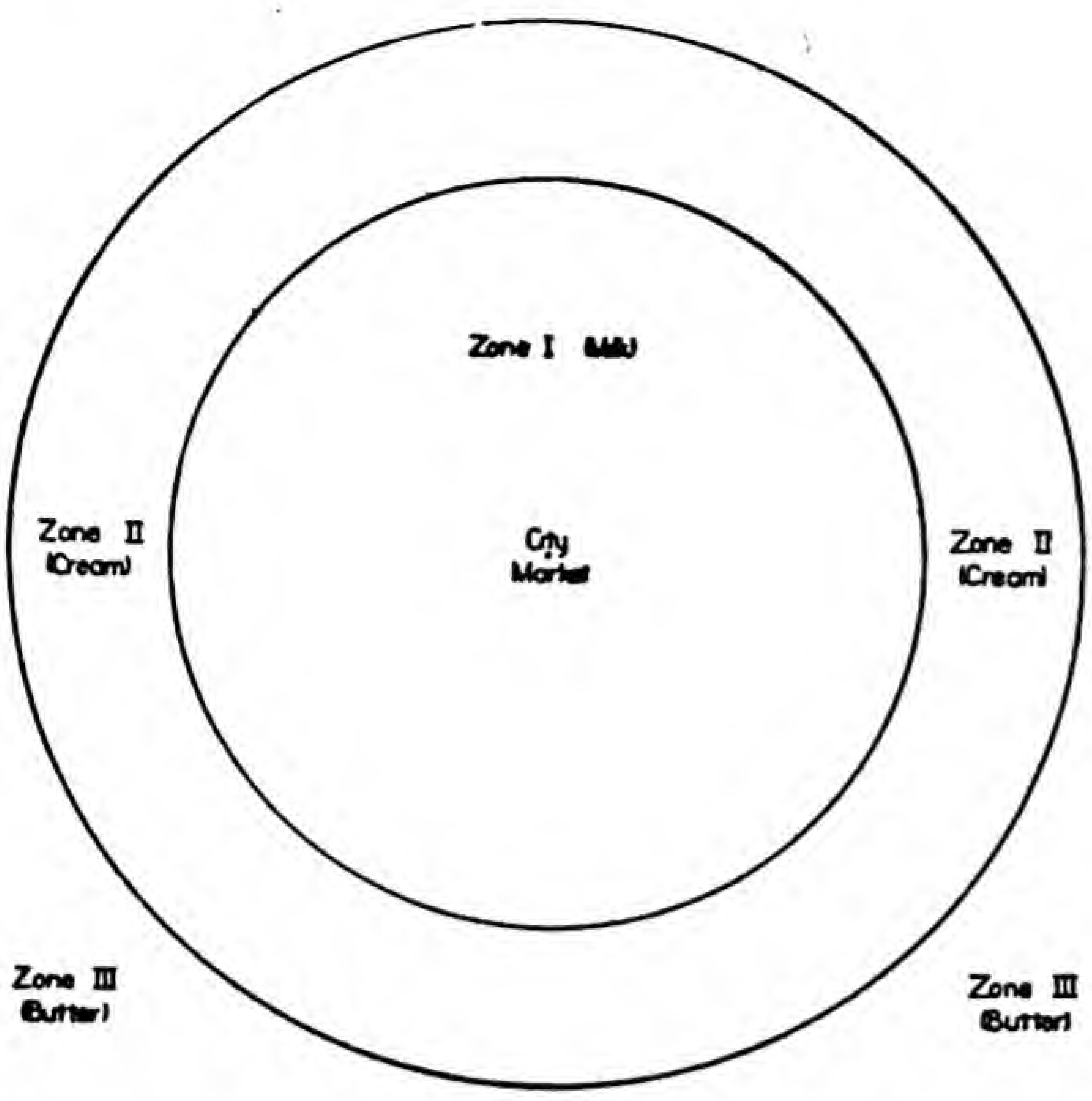


Fig. 9. Scheme of milk production zones under ideal conditions.

supply the milk needed in all seasons, a large contraction and expansion of the territory actually furnishing milk and cream for a city is the natural result. Efforts are made in these areas to reduce the need for flexibility in size of the milkshed by reducing seasonal fluctuations in production.

When a milkshed proves incapable of supplying local market requirements during periods of short production, whole milk may be shipped from distant manufacturing areas under temporary arrangements. In some instances of this sort arrangements are made with health authorities to bring in concentrated milk products to prepare reconstituted milk to supplement local supplies. Such reconstituted milk may be blended with local fresh milk or it may be labeled and sold as a distinctly different product.

ZONES OF PRODUCTION

Cream ordinarily comes from the same milksheds that provide market milk, at least during a great part of the year. During seasons of low milk production some cities permit the importation of cream for fluid use and for ice cream from milk producing territories outside the milkshed. In other cities, however, the health authorities exercise practically the same supervision over milk going into fluid cream and ice cream as they do over market milk, and the shipment of cream from outside the inspected territory is prohibited. In a city where the source of cream is thus restricted, the milkshed includes the supply area for all cream as well as market milk, and tends to be much larger than it otherwise would be because enough milk must be produced within it to supply the demand for both milk and cream throughout the year. To aid comprehension of the relationship between milk and cream supply areas a concept of zones of production may be useful.

One might imagine the supply area around a city as being divided into the three zones depicted in Figure 9. Zone I, located closest to the market, supplies market milk. Zone II, immediately surrounding Zone I, supplies market cream. Zone III, the outer zone, supplies the milk for butter and other dairy products. In practice, Zones I and II would have irregular peripheries and would not have any clear lines of demarcation. Actually, they should expand and contract with the seasons, and therefore would always be in a state of flux; the static lines of the diagram are used simply for clarity in explanation. But, of course, the milkshed as defined by the health authorities cannot change freely. It must lie somewhere between

Zones I and II; it cannot be smaller than Zone I, but it may or may not include all of Zone II, depending upon the regulations enforced with respect to cream. Figure 10 represents a closer approach to what the supply area must look like. The actual picture is complicated still further by the fact that the location of dairy production in the outer zones is influenced more by the relative advantage of dairying in the farming area than it is by the position of the market. The butter producing area is outside the milk and cream zones but not necessarily adjacent to them. It is often more economical to transport cream, butter, and other concentrated products from distant regions that are better adapted to dairy farming than it is to produce them near the market.

SURPLUS MILK

The fact that milk produced in an established milkshed is not always used by the market as market milk or cream gives rise to the so-called milk surplus, which includes that part of the milk supply from the milkshed for which other uses must be found. The disposal of surplus milk at prices that will cover costs of market-milk production is the problem that faces every milk market. This problem becomes more serious as seasonal fluctuations in production increase, as the milkshed is expanded to furnish cream going into different uses, and as the boundaries of the milkshed become more arbitrarily set, because each of these conditions contributes toward accumulation of a greater milk surplus than is naturally expected from the regular fluctuation in production and consumption of milk.

SANITARY REGULATIONS

The principal feature which distinguishes market milk from the milk produced for other uses is the guarantee of high quality that must accompany it. Market milk is subject to the severest scrutiny by consumers because it is the dairy product which receives the least modification in processing. Since it is an essential part of the diet of the entire community and is especially important as a food for infants and children, its quality must be above question. City ordinances commonly specify minimum standards for the butterfat and total solids content of milk, prohibit adulteration, and define the grades of milk in order to insure the food value of market milk. They also regulate sanitary conditions on farms where market milk is produced and in processing plants where it is handled, supervise the processing operations, and designate standards pertaining to bacterial counts and sediment tests—measures designed to protect the health of the community. State regulations supplementing those of municipalities usually pertain to diseases of cattle and conditions in creameries and other processing plants operating outside the sphere of municipal authority. In some instances they are designed to standardize the often dissimilar and divergent city ordinances by serving as minimum requirements for the commonwealth. The enforcement of these sanitary regulations is performed by municipal and state boards of health.

Sanitary regulations applied to market-milk production have been of

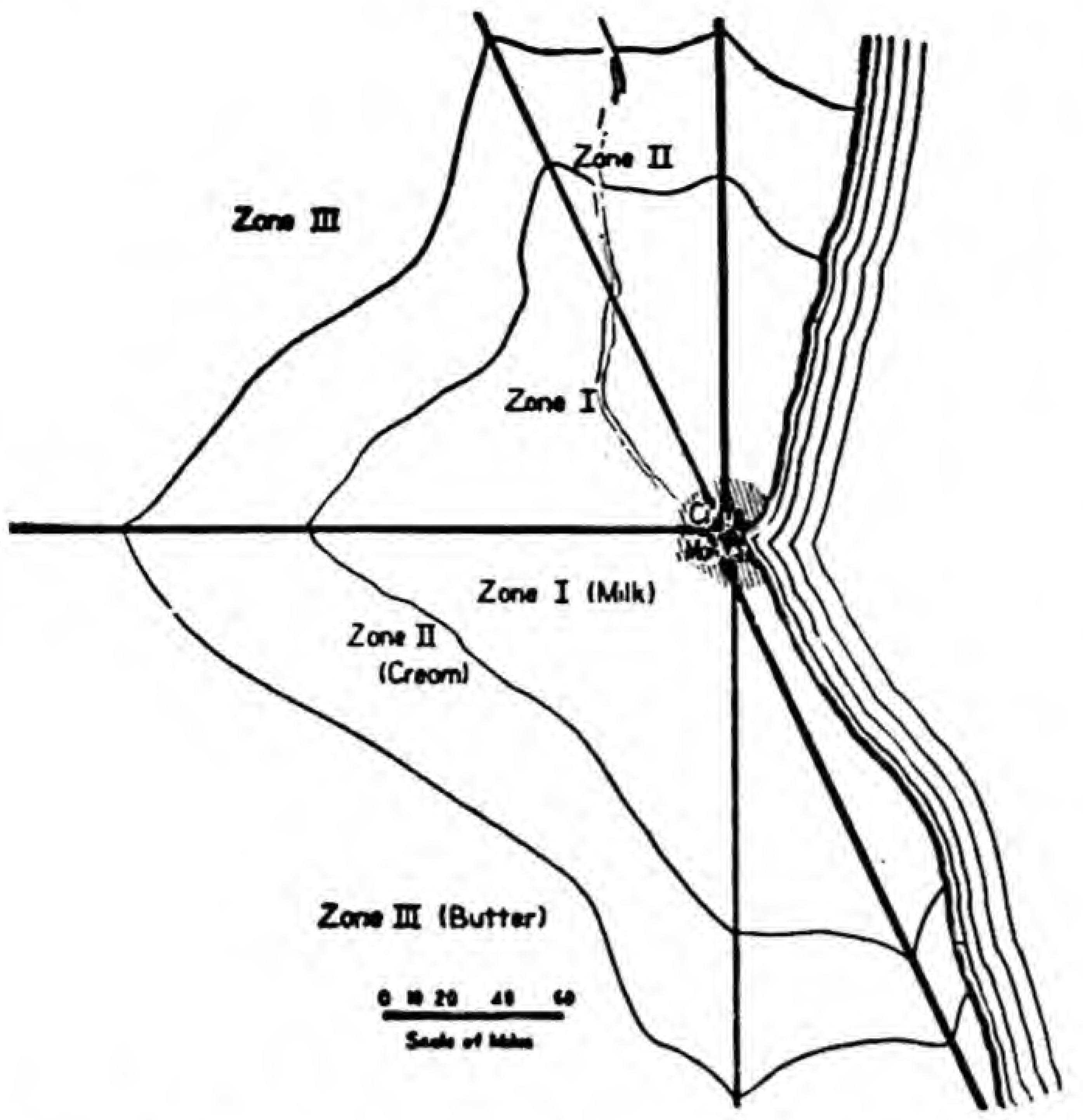


Fig. 10. Scheme of milk production zones under practical conditions.

unquestionable value in fostering production of clean milk. However, many producers as well as consumers contend that the regulations are sometimes used for other purposes as well. Producers outside the milksheds, and often within them, claim that existing ordinances impose regulations which are unjustifiable from a health standpoint, in order to limit market-milk supplies and thereby permit price manipulation. Enforcement authorities are at times accused of yielding to the pressure of market interests in forming their policies. Such charges are not without merit when the ordinances are exposed to political influence, when the specifications vary widely between essentially similar markets, and when co-operation between the health authorities in different localities is lacking.

TRANSPORTATION

Transportation of milk from the source of supply to the processing plant is an essential part of market-milk production. Since milk is a heavy, bulky, perishable fluid it must be delivered promptly in a reasonably fresh condition, a requirement which can be fulfilled only if the milk is kept cool from the time it leaves the cow until it is pasteurized. As a milkshed becomes larger the problem of meeting these transportation requirements becomes increasingly difficult. With the growth of markets as well as improvement of transportation facilities, methods of transporting milk to market have changed materially.

When specialized market-milk production was first begun practically all milk was brought to market by horse and wagon. Although horse-drawn vehicles are still used in some small markets, this method for delivering milk has been superseded in sizable markets by railroads, and motor trucks.

Rail transportation of milk was started before 1850 in the New York and Boston milksheds, where it has been used extensively ever since. From the time that milk cans were carried only in baggage cars, rail shipments of milk have been made faster, more convenient, and less expensive by the introduction of special milk trains, refrigerated cars, and glass-lined tank cars. Many markets adopted railroad transportation for a time, but it is now important in relatively few markets such as Boston and New York which received 53 and 40 per cent, respectively, of their milk by rail in 1946. Only 7 per cent of the milk supplies for Philadelphia were so received. Arrivals of cream by rail in Boston, New York, and Philadelphia,

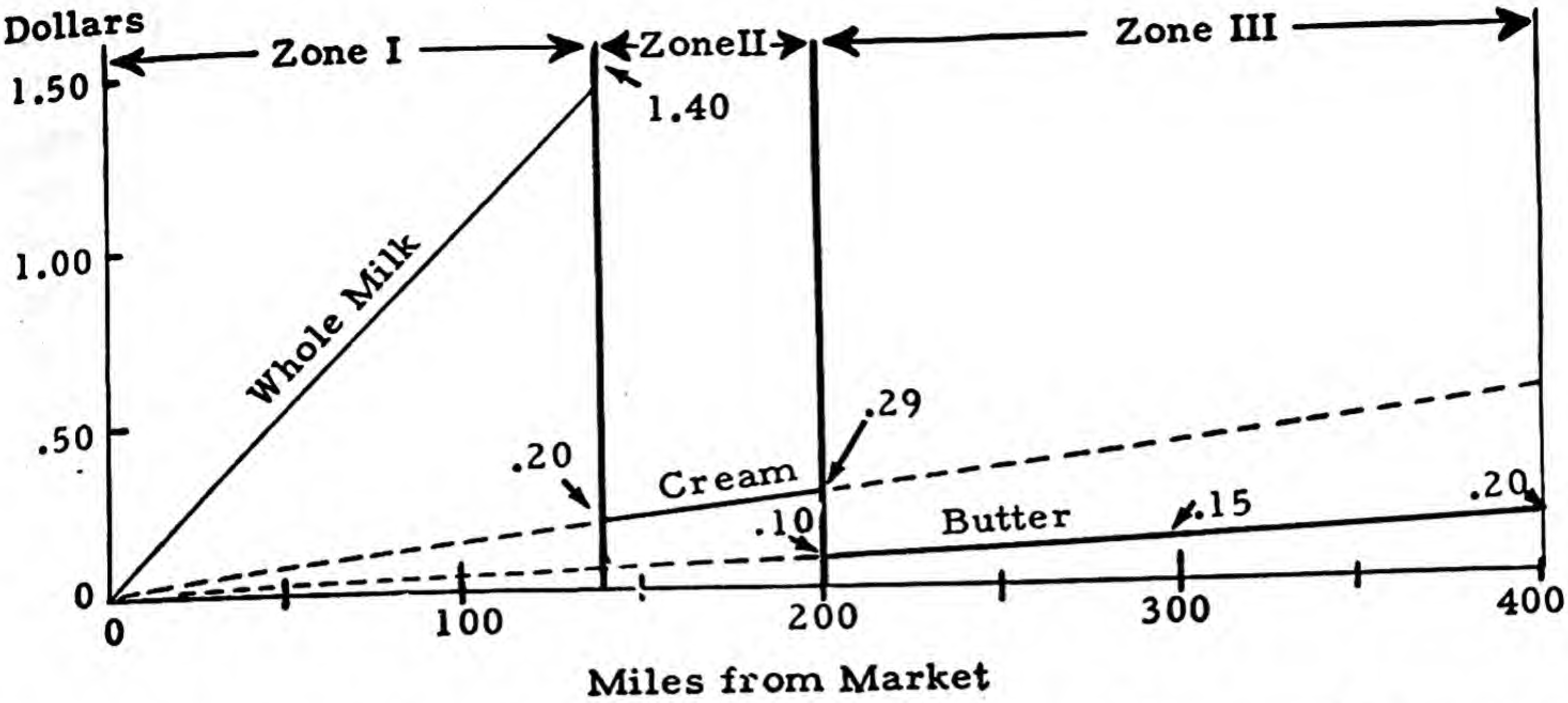


Fig. 11. Cost of shipping 100 pounds of milk as whole milk, 30 per cent cream, or butter from zones I, II, and III.

however, were quite heavy amounting to 94 per cent, 79 per cent, and 75 per cent, respectively, in 1946. This method of transportation is most economical where large volumes of milk and cream have to be shipped more than 100 miles to market.

Where a large volume of milk must be brought into a city from a long distance, milk companies have tended to establish country milk stations which are used to accumulate milk from many farms so that it can be shipped to market in car lots. In some country plants the milk is just collected and transferred to tank cars or refrigerated cars, but in others it is pasteurized and even bottled before it is shipped to the city. Occasionally these country plants are used to collect market milk only during the seasons of short production; the rest of the year they are used as manufacturing plants for the production of cream, condensed milk, butter, and other concentrated dairy products into which surplus milk is converted. In 1944 there were about 140 country plants in New England, of which 104 served the Boston market, about 18 the New York market, and the balance supplied secondary New England markets.

At the present time over 90 per cent of the milk delivered to milk markets is carried by motor vehicles. Truck transportation has been gradually replacing wagons and railroads since 1915, and now many markets, such as Buffalo, Cleveland, St. Louis, and San Diego, receive all their milk in this manner. Farmers close to market tend to haul their own milk in small trucks and automobiles. Farther out from market, where this is inconvenient or too expensive, larger trucks cover regular milk routes, picking up the farmers' milk cans, taking them to the city milk plants. Still further out some of these milk routes terminate at main highways, the milk being transferred to heavier trucks or trailer trucks which haul milk from several routes to the city. In some places country milk plants are operated to facilitate the accumulation of milk for shipment in glass-lined

or stainless-steel tank trucks which hold from 3,000 to 4,000 gallons of milk.

Both railroad and truck transportation have proved to be quick, efficient, and dependable methods for carrying milk to large markets. Truck transportation, however, is definitely superior for short hauls because the milk can be collected from farmers at the most convenient times and can be delivered directly to receiving tanks of milk plants. Near the city the roads are usually improved and kept open the year round, and therefore trucks are seldom delayed by bad weather conditions. In more remote rural districts where the roads are poorer and the hauls longer, truck transportation tends to be more difficult and expensive.

TRANSPORTATION COSTS

Prices charged for trucking milk to market are not very closely correlated with actual costs. In many small milksheds fixed rates are established for hauling milk, without regard to differences in road conditions or distances. Even in large milksheds where differentials exist the rates do not correspond closely to the differences in actual hauling costs. These truck rates and costs are also frequently disproportionate because of overlapping or duplication of competing truck routes, and because differences in costs related to variations in size of deliveries from different farms are not fully taken into account. This tends to give undue advantage to small milk producers and producers located far away from the market and causes dissension among competing producers in different parts of a milkshed. Railroad transportation charges are usually more equitable because of the zone rates that increase regularly with hauling distance.

Theoretically, charges for transporting milk to market should rise progressively the farther the distance from market, since the distance to be traversed is greater and since hauling conditions are usually more difficult. Ultimately the point is reached where it no longer pays to send whole milk to market because transportation costs over the distance are too great. Beyond this point, cream can profitably be separated and shipped to market, for it represents only a fraction of the volume and weight of the whole milk from which it is produced, and therefore costs less to transport. Cream should come from the outer fringes of the milkshed if the market is to be supplied with both milk and cream most economically. Similarly, butter, which is an even more concentrated form of milk, should be supplied from areas farther away from market than the cream supply area.

These differences in transportation costs for the various dairy products are the fundamental reasons for the existence of the zones of production outlined in Figures 9 and 10. Figure 11 illustrates what the approximate costs of transporting 100 pounds of milk or its equivalent in cream or butter from the different zones would be if it is assumed that it costs one cent per mile to transport a hundredweight of goods. Cream containing 30 per cent butterfat weighs only about one-seventh as much as its equivalent in 4 per cent milk, and butter containing 80 per cent butterfat weighs only one-twentieth as much as its equivalent in 4 per cent milk.

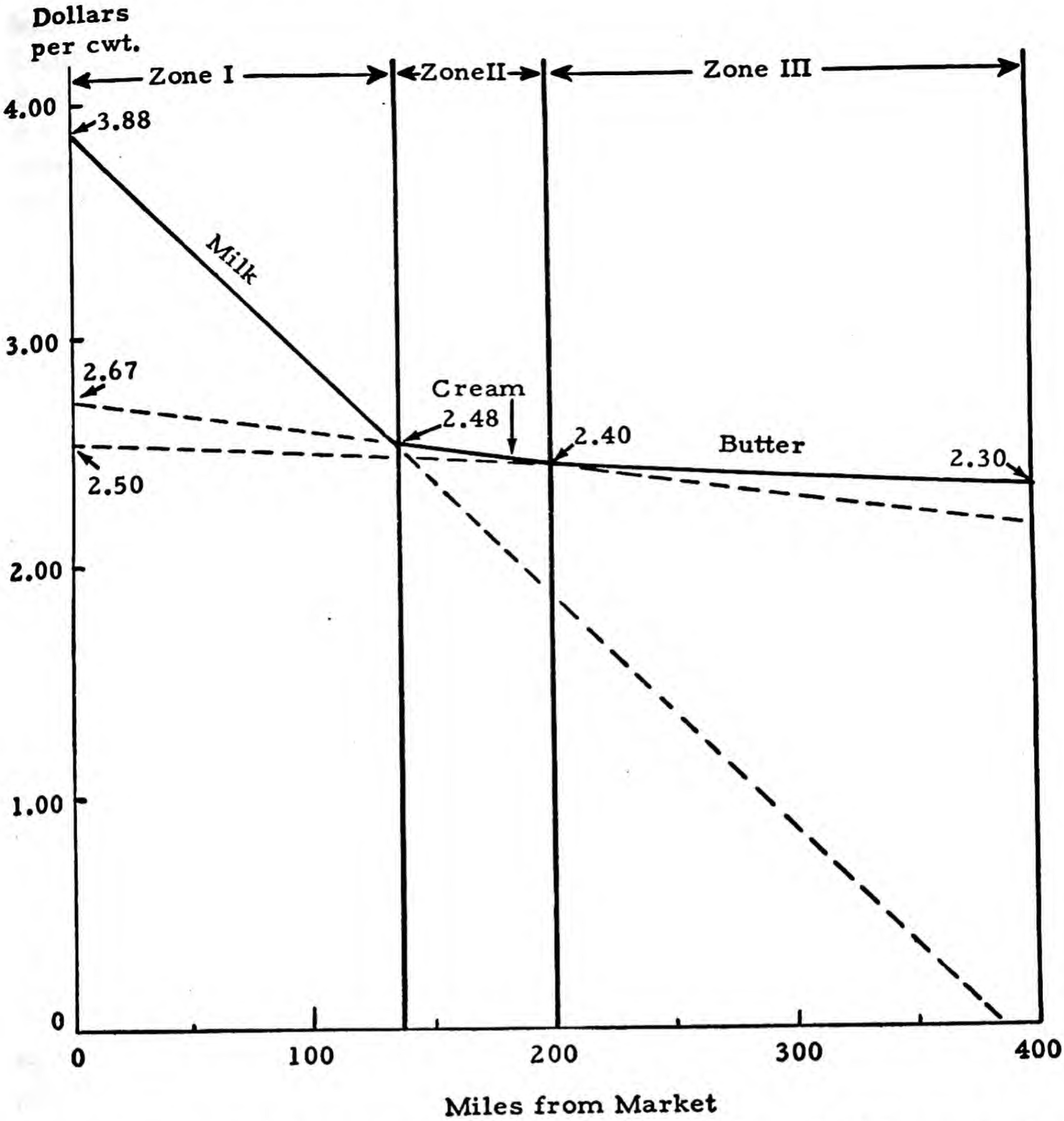


Fig. 12. Transportation costs as they affect the prices of dairy products. Prices of 100 pounds of 4 per cent milk sold as market milk, 30 per cent cream, and butter in the different zones of production when butter sells for 50 cents in the market and the transportation rate is one cent per hundred weight per mile. This diagram takes into account only the transportation cost factor.

Therefore, under the assumed rates, the cost of shipping 100 pounds of 4 per cent milk in the fluid form would be one cent per mile; as 30 per cent cream it would cost one-seventh cent per mile; and as butter, one-twentieth of a cent. Figure 11 simply serves to point out how wide these differences in transportation costs become in the different zones.

Obviously, prices for milk and cream on the market must be sufficiently high to compensate shippers for these higher transportation costs; otherwise only butter would be sent to market. Figure 12 shows what the prices

of these products would be on the market and in the different zones of production as the result of the differences in transportation costs assumed above if the market price of butter were 50 cents per pound. Since 5 pounds of butter can be obtained from 100 pounds of milk containing 4 per cent butterfat, a farmer located 400 miles from market would receive \$2.30 for 4 per cent milk shipped to market in the form of butter. At the same time a farmer located 200 miles from market would receive \$2.40 for the same milk sold as butter as shown in the table below. But suppose

At 400 miles		At 200 miles	
Return from butter:		Return from butter:	
5 pounds at \$.50	\$2.50	5 pounds at \$.50	\$2.50
Less transportation costs:		Less transportation cost:	
400 miles at \$.0005	.20	200 miles at \$.005	.10
Net return	\$2.30	Net return	\$2.40

These computations disregard the costs of manufacture for the sake of simplicity.

the farmer's milk at the 200 mile mark (the outer edge of Zone II in Figure 12) were needed to supply cream for the market. Then the net return from cream must be at least \$2.40 at this point or he will prefer to ship butter. This would require a market price of \$2.667 for 100 pounds of milk in the form of cream, since the cost of transporting the cream would be \$0.267.[1] To the farmer located 140 miles from market the same cream would bring a net return of \$2.481, because he has a transportation cost of only \$.186 to subtract from the \$2.667 market price.

If Zone I extends out to the 140 mile point, the price of milk must be high enough to pay the farmer located at that point at least as much as he could get for his cream. This being the case, the market price of milk must be at least \$2.481 plus the \$1.40 required to transport the hundredweight of milk to market, or \$3.881.

While this relationship between milk, cream, and butter prices due to transportation costs is fundamental in maintaining the proper balance of these products on the market, because of the many other conflicting circumstances it is seldom sensitive enough to cause price adjustments between them to follow with mathematical precision. In the foregoing example it was assumed that it cost one cent a mile to transport a hundredweight of milk or its equivalent in cream or butter. If the market price for fluid milk remained unchanged but unequal transportation rate changes occurred it is apparent that the boundaries of the respective production zones would be likely to shift. For example, if there were a relative decrease in the transportation rate for fluid milk as compared with the rate for butter, the fluid-milk zone would tend to expand, and vice versa.

In addition to transportation costs other factors influencing this equilibrium of prices include the costs of meeting the sanitary requirements,

[1] One hundred pounds of 4 per cent milk yields 13.33 pounds of 30 per cent cream. To ship this cream 200 miles at 1 cent per hundredweight per mile costs (200 miles x .133 cents) 26.7 cents.

the value of skim milk to the farmer, and the facilities the farmer has available for separating milk, on the one hand, or for cooling and caring for it as whole milk, on the other hand. The relationship between prices of fluid milk and manufactured dairy products is particularly close in areas where concentrated products form the major outlet for milk.

FARMERS' OUTLETS FOR MILK

Several alternative ways of selling milk are open to farmers in market milksheds. They may (1) sell the milk directly to consumers, (2) sell it to a milk dealer, or (3) assign it to a milk sales agency to sell it for them. Each of these methods has certain advantages and disadvantages, the strength of which vary with the circumstances surrounding the individual producer, who seldom has an equal opportunity to use any of the three methods, but who usually is able to exercise some choice in the matter.

PRODUCER-DISTRIBUTOR

If a farmer decides to sell his milk directly to consumers and become a producer-distributor, he must acquire bottling equipment, bottles, and a truck to deliver the milk. Unless he produces certified milk by complying with the stringent sanitary regulations and by meeting the precise quality requirements prescribed by county medical commissions, he must abide by the city health regulations; this, in most cases, involves the installation of pasteurizing equipment. In addition, he must be prepared to handle his own surplus milk during seasons of heavy production. Few farmers are located close enough to primary markets and have sufficient capital and labor to undertake these responsibilities of milk distribution along with their farm production tasks. Furthermore, health authorities have virtually eliminated producer-distributors in some of the larger cities by outlawing them or by enforcing prohibitive regulations against them. For these reasons most farmers in large milksheds prefer to concentrate their efforts on farm milk production and leave the marketing, or processing and distributing functions, to others. In metropolitan areas such as New York, Philadelphia, and Cleveland, less than 1 per cent of the milk is delivered by producer-distributors, who are found only in outlying suburban areas.

Producer-distributors are usually more important in smaller markets, where they are closer to their customers and where health authorities are less exacting. They are especially strong in the South and West, where they still deliver substantial percentages of the milk in cities like Atlanta, Georgia, and Kansas City, Missouri.

SALES TO DEALERS

Prior to World War I practically all producers who did not distribute their own milk sold it directly to city milk dealers, each producer making his own independent bargain for the sale. Many farmers still sell their milk this way, particularly in small milksheds where the dealers and producers can keep in fairly close contact with each other and have an

understanding of their mutual problems, and therefore can come to satisfactory individual agreements concerning prices for milk. Under these conditions the dealers usually contract to accept all the farmers' milk at a fixed price. To do this they shoulder the responsibility of finding uses for all the milk, and the proportions of the milk that must go into the different products are taken into account when the price is agreed upon. In larger cities, however, some dealers pay their farmers for milk according to the uses that are made of it. This is especially true when they are in competition with co-operative milk marketing associations.

CO-OPERATIVE MILK-MARKETING ORGANIZATIONS

In larger milksheds most milk producers never see the dealers who receive their product, and the problem of selling milk is not so simple. Here the dealers, receiving milk from thousands of competing farmers, are large, powerful, and relatively few in number—factors which give them definite bargaining advantages in buying milk from individual farmers. Under such conditions the farmers need some convenient means whereby they can carry on their business relations with milk buyers on a more equal footing. This need was augmented during World War I; taxes, wages, and feed prices were rising and causing dairy farmers' costs to mount, but city milk dealers refused to pay them more for their milk because to do so would necessitate an increase in retail price of milk. This action the dealers were reluctant to take because the retail price had remained the same for years and people were accustomed to it. To change the price would give rise to public indignation that they feared would react against their business. In order to get results, then, the farmers were obliged to band together and, by means of collective bargaining, force the dealers to accede to their demands. Co-operative milk sales organizations were formed for this purpose.

Maladjustments in production which occurred during the readjustment period following the War resulted in serious price recessions and put milk producers in even more unfavorable circumstances. Consequently, the number of milk co-operatives increased rapidly in the intervening years between World Wars I and II. Approximately 40 per cent of the fluid milk is handled by co-operative milk marketing associations which are now to be found in most large milksheds handling the milk sales problems for farmers.

These co-operative agencies may be divided into three principal classes: (1) bargaining associations which serve primarily as sales agents for their members, (2) operating or processing associations which engage in the physical handling of milk which may be done in conjunction with bargaining functions, (3) distributing associations which perform all marketing functions and sell milk at retail directly to consumers.

The purely bargaining association is the simplest type of market-milk co-operative, for it is concerned only with the sale of its patrons' milk to processors and distributors. It does not engage in physical handling of milk and does not ordinarily take title to milk, but acts primarily as a sales

agency bargaining for prices on a collective basis and attempting to see that all the milk is satisfactorily disposed of with every patron receiving equitable treatment. In addition to negotiating terms of sale, milk-bargaining associations often serve patrons by systematizing delivery of milk to the market to reduce transportation costs and by helping patrons to adjust their production to market needs by instituting systems of payment that discourage large seasonal fluctuations in production. None of these activities require heavy outlays of capital or operating expenses. Consequently, these associations operate on a relatively small fee which usually amounts to a few cents per hundred pounds of milk sold. This type of association is exemplified by the Interstate Milk Producers Association of Philadelphia, the Dairymen's Co-operative Sales Association of Pittsburgh, and the Sanitary Milk Producers of St. Louis.

The operating or processing types of fluid milk associations differ in that they usually take title to milk, and they take physical possession of all or a substantial part of the milk sold through them. Either they bargain with milk dealers for that part of the milk which the dealers want, converting the rest of it into manufactured products in their own plants, or they process and distribute all the milk themselves. These co-operatives take responsibility for utilizing milk which is not needed for market milk and cream by converting the surplus milk into salable products and they distribute the net proceeds from all the milk equitably among the membership. This type of association requires a great deal of capital, much of which is obtained from member stockholders. Its personnel and operating costs are necessarily greater than those of the purely bargaining association and are in keeping with the greater service that it renders. Examples of operating or processing associations are the Des Moines Dairy Marketing Association which manufactured about 30 per cent of its milk in 1946 and the Twin City Milk Producers Association of St. Paul and Minneapolis which in 1946 sold about 57 per cent of the whole milk receipts to fluid milk outlets, separated about 37 per cent of receipts for market cream and butter, and processed the remaining whole milk and the by-products, skim and buttermilk, into manufactured products in its six plants.

Some of these co-operative associations have had a tendency to spread out over several markets in a major metropolitan area or on a regional basis. When this occurs, the co-operatives may achieve the status of very large business organizations. For example, the Dairymen's League Co-operative Association of New York furnishes approximately one-third of the market milk for New York City and substantially higher percentages of the milk in a number of surrounding markets. In 1946–47 its 27,000 members located in six states produced about 2.4 billion pounds of milk for which they received approximately 110 million dollars. The League in that year operated 105 country plants, of which 94 were fluid shipping plants and 11 were manufacturing plants. In addition, the League operated 18 city plants and engaged in wholesale and retail milk distribution, selling its manufactured products and fluid milk under the well-known "Dairylea" brand. In so far as the League engages in retail distribution, it

demonstrates that these co-operative associations cannot be strictly classified as to type. In this, as well as several other instances, retail distribution operations are distinctly of secondary importance compared with bargaining and processing functions.

About 100 co-operative associations may be classed as primarily engaged in retail milk distribution to consumers. As a rule, co-operatives organized for this purpose are located in small towns and have limited memberships. Notable exceptions are to be found, however, in Cincinnati, Ohio and Milwaukee, Wisconsin, and in a few somewhat smaller cities. Retailing co-operatives require far more capital relative to the amount of milk handled than do other types, because of the expensive equipment and supplies and the large labor forces and current operating funds that they need. This appears to be the principal limitation to an extensive development of retailing milk associations.

Co-operative associations that engage in bargaining hesitate to undertake the functions of retailing because it at once makes them competitors with their usual customers, the milk distributors. Where they do so it is usually in secondary or segregated markets. Other types of co-operatives that engage in retail distribution are made up primarily of co-operative creameries located in little towns where specialized market-milk processing plants have not been established.

PAYMENT FOR MILK

The universal problem confronting every milk market and every type of sales organization is one of paying for milk in a fair and acceptable manner. It is a perplexing problem because of the so-called surplus milk, which brings a lower return than milk that is bottled or sold as cream. Not all producers contribute equally to the surplus because not all have seasonal flunctuations in production of the same magnitude. Furthermore, the milk produced by those farmers close to the market can hardly be considered surplus milk at any time because it can always be taken to market most economically. Still, the market cannot do without milk produced by outlying farmers at least part of the time. Who, then, should receive the lower returns from the surplus milk? And how should the milk be paid for?

Obviously the question of milk payment does not strike all producers alike. Producer-distributors handle their own milk in all seasons; their problem is resolved into one of finding outlets for all their milk throughout the year. Ordinarily farmers' retail co-operatives are small, with relatively few patrons located within a limited area, and producing under similar conditions, and therefore they are usually able to prorate the proceeds from the milk among the patrons according to the amount of milk delivered without running into serious discrepancies. But when farmers sell their entire milk production to dealers the problem of handling the surplus is shifted to the buyers. The simplest way for dealers to buy milk is to pay regular producers one price for all the milk delivered. This system

is used so long as it is accepted by producers, but it requires some modification on larger markets, where surpluses may reach tremendous volumes. Large dealers often resort to paying for farmers' milk according to the use they make of it, in order to get the proper seasonal price adjustment. The price must fluctuate with the supply; the payment of a low price during the flush season and a high price during the short season tends to level out production, but a seasonal fluctuation in milk production is inevitable, and a price system based on the use of milk cannot prevent it entirely.

In practice, when the supply of milk from regular producers is more than the dealers need, the surplus is handled by the dealers, who use it to manufacture other dairy products. On the other hand, when supply from the regular producers is insufficient to meet the market milk needs the dealers contract with farmers or creameries farther out from market to send them milk or cream temporarily, until the regular producers are again producing enough milk for market-milk purposes.

To secure this temporary milk from outlying producers dealers must pay these producers higher prices than they can otherwise obtain from the creameries and condensaries to which they can sell their milk. In fact, the difference in price must be great enough to justify the additional expenditures necessarily incurred by producers in adjusting their production methods to conform to market-milk standards. Only while the milk is being used for market-milk purposes can dealers afford to pay this higher price. But having once made the necessary changes to comply with the sanitary regulations, these outlying farmers are not content to remain as just temporary market-milk producers, and they continue to compete with producers near the market throughout the year. This adds to the surplus of milk during the flush season and causes the milk price to be lower for all producers in the market at that time, and resentment rises among the inlying producers. It is this conflict of interests that makes it possible for milk dealers to play one group of farmers against the other and thus force all milk prices down. The farmers' recognition of the fact that the milkshed can be expanded much easier than it can be contracted and their cognizance of the futility of independent action in coping with the problem cause them to resort to co-operatives to deal with distributors.

But co-operative milk-marketing associations cannot have part-time members, nor can they afford to refuse membership to farmers who may otherwise compete with them; therefore they attempt to devise systems of payment that will be acceptable to all farmers within the milkshed. This has proved to be a most difficult task; milk strikes, price wars, rival co-operatives, and general discontent among producers having resulted from many attempts to accomplish it. In fact, so much strife existed in milk markets during the depression that State Milk Boards and the Agricultural Adjustment Administration were given far reaching regulatory powers to iron out the difficulties encountered.

Each market tends to have its own peculiar local problems, and each

co-operative has attempted to arrive at its own independent solution. As a result, few generalizations can be made with reference to the system of payment adopted. Several underlying conditional factors can be ascertained, however, and payment methods devised in response to them can be discussed, provided it is clearly understood at the outset that innumerable modifications and exceptions will be found in various milksheds.

Class prices. The first bone of contention between milk producers and distributors concerns the farm price of milk; this involves the question of what proportion of the retail price should go to the producer. When farmers observe a quart of milk, which they sell for 6 or 7 cents, retailing at 14 or 16 cents in a bottle, they question whether they are receiving a reasonable proportion of the return. The answer is that not all milk produced within a milkshed can be bottled and sold as market milk, because of the daily and seasonal fluctuations in demand and supply. People tend to buy less milk and cream on Sundays and holidays and more on Saturdays than on other week days and more on hot days than cold days, and this variation in sales from day to day forces distributors to keep a reserve of from 10 to 20 per cent of their average milk sales in order to accommodate these greater demands when they arise. The unused reserve must necessarily go into some other less remunerative dairy product. Seasonal variations in supply are not offset by similar variations in demand. They add to the amount of milk which is produced for market milk but which must be used for other purposes, because the lowest production point determines the amount of territory which has to be included in the milkshed. The larger the milkshed and the greater the irregularity of production and consumption of market milk, the greater the proportion of milk which must be regarded as surplus and which must be used in other products.

Any farmer can see why not all of his milk will bring the highest return, but when he observes that the retail price of market milk is slow to change and seems to have little relation to the supply, he feels that he has an inalienable right to a higher return for that portion of his milk which is bottled and sold as market milk or cream. The farmer, therefore, demands, through his co-operative marketing association, that he be guaranteed payment for his milk that is commensurate with the use made of it. The class-price systems of milk payment were introduced in answer to these demands. At the present time the majority of sizable milk markets employ class-price systems of payment through which farmers receive two or more rates for different portions of the milk that is produced and sold in city milksheds.

The so-called class I milk is presumably bottled and used as market milk and, therefore, receives the highest rate. Class II milk is supposed to be used as market cream, and brings a lower price than class I milk. The rest of the milk, which is converted into butter or other dairy products before it is sold, gets the class III price, which is even lower. This classification is not consistent in all markets; milk and cream used in ice cream and other special products are often included in separate classes with

similar price differentials, usually intermediate to classes I, II, and III as they are here defined.

Pool prices. At a receiving plant the milk supplied by each patron is weighed and recorded, but no differentiation is made; it is all thrown together in the receiving vats, and what is not bottled for market milk is diverted to some other use. In other words, the milk is all pooled together in the plant, and the computation of the amounts of each farmer's milk going into each class is an office procedure which is performed at the end of each payment period. Where just one dealer is involved this is known as a dealer's pool. The one price paid by some dealers is theoretically a composite or average price made up of all the class prices.

Not all dealers use the same proportions of the milk received for each of the different uses. For instance, dealer A may be bottling 88 per cent of his milk, while dealer B, operating in the same market, may be bottling only 67 per cent of the milk received. This means, then, that A's pool price will be higher than B's because a greater proportion of his milk is paid for at the class I rate. A co-operative bargaining association selling milk to all the dealers cannot very well let the farmers shipping milk to one dealer get more for their milk than farmers shipping to other dealers, since all farmers would want to ship to the dealer paying the highest price. In order to rectify such a situation some co-operatives form a market-wide pool.

Theoretically, a market-wide pool throws together the milk from every farmer shipping to the market and distributes the proceeds according to the uses made of all the milk. In practice, the bargaining association accomplishes this by bargaining with all dealers for the same class prices. At the end of each month the dealers report to the association the amount of milk used for each purpose, and from these reports an average price for the market is computed. The dealers are then notified to pay their farmers this price. Those dealers who sold more class I milk than they actually paid their farmer patrons for turn the remainder of the money over to the association, which then reimburses those dealers who paid their patrons for more class I milk than they actually sold. Thus all the producers receive the same average price per hundredweight of milk.

Base-rating system. A uniform price for milk, paid to all producers, is not a fair price, unless it is assumed that they all contribute equally to the market surplus. But those producers who go to the trouble of leveling out their production so that the seasonal variation is reduced are not as responsible for the same amount of class III milk coming on the market as are the producers with a highly seasonal supply. Prior to the entry of co-operatives on the markets many dealers encouraged their regular patrons to level out production by paying them premium prices during the short supply season. This reduced the amount of surplus milk which these dealers had to handle during the seasons of flush production and made it possible to pay these patrons a higher price the year round. When co-operatives entered the market the responsibility of finding an adequate milk supply was theirs; so, too; was the responsibility of reducing the

seasonal variation so that their patrons could receive higher milk prices. Some associations introduced the base-rating plan of payments as a means of encouraging an even production of milk.

Under the base-rating system as it was originally planned a farmer who supplied the same quantity of milk to the city plant every day in the year would receive the highest rate of payment for all his milk, while another farmer who delivered more milk in the spring than he did in the fall would receive a lower price for that part of the milk which was in excess of his lowest or basic supply. In practice, each farmer's base was determined by averaging his daily deliveries during the season of lowest production. Thereafter, throughout the rest of the year, he was paid the premium price for the amount of milk corresponding to his base, and lower prices for the remainder. Thus he was induced to produce more milk during the normally short season, but he had less incentive to produce more than his basic amount in the other seasons. When the base was established by averaging the deliveries for one specified low month, he had a tendency to build up his production for that month to get a high base, and to shift his period of lowest production to either the month preceding or the month following. Such a procedure did not solve the market difficulties, and therefore associations adopted three-month base periods, usually September, October, and November. Even longer base periods have been introduced by some associations in their attempts to satisfy minority interests among producers. This represents only one of the numerous modifications that have been made in the base-rating plans as they are actually administered.

Pooling and base-rating systems combined. The base-rating system is commonly used in conjunction with the pooling system of paying for milk. Theoretically the sum of the farmer's bases should equal the class I sales, since they are supposed to be determined when the supply of market milk is equal to the consumption. But actually the farmers' base is determined as an average production for periods ranging from one to six months, and fluctuations in production that occur within the base period make it necessary to include milk other than class I in the base. At best, the total base milk so determined tends to exceed the class I sales by the amount of the dealers' daily milk reserve and, therefore, only 80 to 90 per cent of it can receive the class I price. Where the class I price is paid to producers on a definite percentage of their base production, the base-rating plan can properly be considered a method for paying regular milk producers on a more equitable basis than either the pooling system by itself or the one-price system.

In some markets, however, associations have chosen not to adjust farmers' bases every year because of some peculiar circumstance that has arisen, such as the occurrence of serious droughts in part of the milkshed during or immediately preceding the base period. The afflicted farmers in these areas argued that bases determined under such adverse circumstances were unfair to them, and the co-operatives, following their policy of attempting to satisfy the entire membership, departed from the original

base-rating plan by continuing old bases. In other instances co-operatives seeking greater control of the market have offered to arrange favorable (large) bases for new members. Many adjustments like these have served to render the base-rating system less effective in accomplishing its original purpose of inducing farmers to engage in more regular production. In fact, the base-rating plan as it has been administered has bred much dissatisfaction among producers, and some markets have been forced to abandon it. Numerous varients of the base-rating plan have been tried but none has proven completely successful or universally applicable. Among the more widely accepted have been quota plans in which the quotas are quite similar to bases except that they are established on different criteria and put-in and take-out plans. The latter usually involve the withholding of part of the payment for milk during the flush season, and the distribution of funds thus accumulated as a supplementary payment for milk delivered in the fall or winter months.

Butterfat differentials. Butterfat is the most valuable constituent of milk and, since the butterfat content of milk is quite variable, allowance has to be made in every milk-payment system for difference in worth due to this factor. Some milk is bought and paid for exclusively on a butterfat basis; that is to say, the market pool is in reality a butterfat pool rather than a milk pool. More common, however, is a system of butterfat differential payments in which all milk price quotations refer to milk with a standard butterfat content, such as 3.5 per cent, and in which, along with the quoted price, there is a specified price differential which applies to each tenth of a per cent of butterfat above or below the stipulated standard. The differential is usually expressed as so many cents per point, let us say 5 cents; this means that milk containing 3.8 per cent butterfat would receive 15 cents more per hundred pounds than 3.5 per cent milk.

Processing and distributing milk. Practically all milk which leaves the farm destined for the city market has to be processed; that used for market milk is pasteurized, some is separated and pasteurized for market cream, and other portions are made into chocolate milk, ice cream, and cheese. In addition, the milk or milk products must be placed in suitable containers before they are delivered to consumers. This processing and bottling or packaging, which requires rather precise and often complicated equipment when it is done on a large scale, is usually performed in specialized milk plants which are to be found in every milk market. After milk is processed it finds its way to consumers via numerous courses. Most of it is delivered directly to homes over regular routes operated by producer-distributors, retailing co-operatives, milk dealers, and peddlers. Milk routes also include wholesale deliveries to hotels, restaurants, hospitals, and retail stores. In small towns and villages the greater part of the milk is distributed by producer-distributors and retail co-operatives operating on a small scale, but in larger cities, where distribution becomes a complex problem, it is largely taken over by specialized milk dealers.

The milk processing and distributing industry tends to operate on a decreasing cost basis; that is, the greater the quantity of milk handled the

lower the processing and distributing costs per unit become. For this reason there is a continual aggressive struggle among milk dealers for more business so that their costs of handling each quart will be less. The successful dealers tend to expand over the entire market, and therefore in most cities a few large dealers deliver the greater part of the milk, and many small dealers compete for the remainder of the business. This situation does not make for uniform costs among milk dealers and is not conducive to a very stable equilibrium on the milk markets.

Strangely enough, however, market-milk prices tend to remain relatively stable. Comparable prices are usually charged by all dealers, and frequent price changes are avoided in order to discourage ruinous price cutting, which is injurious to all market interests. Rather than engage in price competition the dealers confine their activities to service and cost competition. Especially in markets where retail prices are fixed by a market regulatory body, the dealers strive to offer customers the most prompt, convenient, and courteous delivery service, the highest butterfat content, the deepest cream line, the most desirable color and flavor, the most attractive package, and the "cleanest" product. This service competition often leads to unexpected and seemingly inexplicable complications, such as discrimination against Holstein milk by some dealers and excessive duplication of delivery services manifested in most cities, where the trucks of many dealers cover the same territory.

In their search for possible cost reduction dealers look at the costs of raw materials, of labor, and of operating equipment, their main sources of expense. The raw materials, milk and cream, which consume in the neighborhood of 40 to 60 per cent of the consumers' expenditures, constitute the largest item of dealers' expense and seem to offer the best opportunities for cost reduction. But in the current market organization, milk producer's co-operative associations function to forestall any undue cutting of raw material costs. The system of class prices and the provisions for checking on weights, tests, and uses of milk, prerogatives which are stipulated in the co-operative sales contracts, are measures employed by the associations for this purpose. Thus, farmers tend to be protected from exposure to dealers' competition where co-operative associations function effectively.

About 25 per cent of every consumer's dollar spent for milk is paid out as wages for labor used in processing and distributing. Since this represents the next highest expense confronting the dealers, wages might be expected to suffer when dealers are looking for ways and means of cutting costs; but in most large or middle-sized cities dairy laborers are protected by unions which bargain collectively for milk-wagon drivers' and plant employees' wages. These unions, notably strong in many markets, tend to raise dairy labor costs by setting minimum-wage scales, by increasing sales commissions, and by improving working conditions. The latter is accomplished by placing restrictions on working hours and on sizes of milk routes, and by lengthening vacation periods with pay.

Operating costs other than wages, which absorb 15 to 20 per cent of the

consumer's dollar, are under the direct control of the dealers themselves. Minimum processing requirements are specified in health regulations, but usually dealers try to employ the best possible handling methods and the most up-to-date equipment both inside and outside the plant as means of giving the public a favorable impression of their products. By its very nature the dairy manufacturing business has much unutilized capacity entailing capital and upkeep costs, because it uses expensive equipment, looks toward expanding markets, and deals with seasonal fluctuations in purchases and sales. Dealers attempt to make more efficient use of this excess capacity and thereby reduce unit costs. This they do by increasing their business through advertising or by turning to supplementary enterprises, such as the delivery of orange juice, tomato juice, butter, eggs, and similar products on their routes along with milk and cream. The combination of milk and ice cream plants is common, and most milk dealers manufacture and deliver such special milk products as cream cheese, cottage cheese, chocolate milk, buttermilk, and sour cream. In fact, dealers often report their greatest profits in side-line enterprises, but the allocation of costs and profits is too dependent upon accounting procedure to accept this as a generality.

Where there is a great variation in the sizes and efficiencies of plants with little variation in prices, as is the case in the milk business, equally large differences in the profitability of the companies are bound to exist. The high administrative salaries and the wide profits reported by some of the larger, more efficient concerns are a natural result which is often subjected to public ridicule, especially when milk companies are associated with holding companies operating on a regional or nation-wide market. But opposition to obvious private monopolies and the inclination to protect the "little fellow" and preserve competition often lead consumers to accept milk prices which are high enough to keep less efficient dealers in business. These milk prices in large markets are in some instances determined by arbitration conferences at which the farmer, labor, and dealer interests are well represented by their respective organizations, and consumers are ostensibly represented by civic leaders selected for the purpose.

Some price competition occurs on those markets where milk can be bought through stores on a cash and carry basis at a lower price per quart bottle. Chain groceries and stores handling dairy products argue that such a price differential is justified inasmuch as the costs involved in house to house deliveries and bad debts are eliminated. However, milk-wagon drivers generally and sometimes farmers are opposed to the existence of such differentials in retail prices—the former because their services tend to be used to a lesser extent, and the latter because they fear that a reduction in class I milk prices will ultimately follow. In markets where labor unions and farmers' associations have the power to enforce their demands store price differentials are sometimes prohibited or are kept low.

Retail milk prices are quite stable; during a period of declining commodity prices they tend to lag, but eventually they must decline somewhat when other prices fall. Dealers' margins are rather inflexible because of

the rigidity of union wages and the high proportion of fixed costs, including interest and taxes on the large fixed investments, which go to make them up. Therefore, the farmers usually bear the brunt of a decline in milk prices because they have little effective control over milk supplies and because the proportion of class I milk becomes smaller as demand drops. Disturbances among dairy farmers are consequently not uncommon during a depression. They observe the relative stability of retail milk prices while the farm milk prices are falling and the dealers' margins are widening, a situation that appears grossly unfair to them. Objections are raised by starting rival co-operatives, by establishing roadside stations to sell milk at cut prices, by promoting milk strikes, and by other actions which tend to demoralize and break down the whole market structure. During a period of rising prices quite the opposite is true and farmers usually get the major benefit from the price increases.

These bitter disputes between farmers concerning who should bear the surplus milk, between farmers and dealers about the sizes of margins, between dealers and laborers over wages, and between dealers for business have led to frequent public investigations of the industry. To reduce the strife all sorts of suggestions for reform have been made, the most drastic proposal being that milk be declared a public utility and the industry either be operated by municipalities or be subjected to public utility control. While the likelihood of the milk industry being made a public utility is rather remote because of the impracticability of controlling the supply, there has been a tendency toward more extensive public regulation. This tendency has been demonstrated by expansion of state milk control boards, and of federal milk marketing agreements and orders issued pursuant to the Agricultural Marketing Agreement Act of 1937. State controls have subsided with periods of rising prices, but federal regulations have proved to be more durable.

Federal regulation is concerned primarily with establishment of minimum producers prices as a means of achieving market stability. It is characterized by frequent recourse to public hearings to consider adjustments in response to changing conditions, and thereby offers opportunity for public debate of problems before a generally acceptable referee or regulatory body. In its administration considerable effort has been made to co-ordinate prices between markets that compete for supplies, and to overcome the rigidity of fluid milk prices. One of the features of the attempt to gain flexibility has been the introduction of milk price formulas in which reliance is placed upon prices established in other diary products markets such as the butter, cheese, evaporated milk, and cream markets to achieve prompt and automatic changes in fluid-milk market prices. Some formulas, more recently developed, rely on other indicators of changes in costs or demand such as feed price indexes and department store sales. This type of formula is used primarily for pricing class I milk.

Chapter 5

ECONOMICS OF THE BUTTER INDUSTRY[1]

THE BUTTER INDUSTRY, WHICH HAS BEEN DEVELOPED FROM THE AGE-old trade of butter making, is next in importance to the market-milk industry as an outlet for milk. This industry has for its purpose the concentration of butterfat from milk into a compact, palatable product that is widely used for bread spreads and cooking. Although the production of creamery butter in 1944 and subsequent years was considerably under 1.5 billion pounds owing to the exigencies of war, normally from 1.7 to 1.8 billion pounds are churned annually from at least 20 times that amount of milk. The value of this annual production well exceeds half a billion dollars, and some 3,500 plants employing about 25,000 people are engaged in the industry.

CREAMERY BUTTER

Until about a century ago all butter was made on the farms where milk was produced, but since that time butter making has been gradually shifted to creameries. At present 80 per cent of the butter is made in factories, and virtually all butter entering the commercial trade is so made. Farm butter making is now confined to those areas where the quantity of milk available for butter is small and where most of the butter is consumed in the farm home or peddled in neighboring communities. This discussion will deal almost entirely with creamery butter, which, from the point of view of economic significance, is by far the most important.

Creamery butter making began in the latter part of the nineteenth century when neighboring farmers started to pool their milk to let attendants separate cream by gravity methods and churn it. Later, farmers skimmed their own milk and delivered cream to the factory for churning. Each farmer received his share of proceeds from the sale of the butter according to the weight of the milk or cream delivered by him. It was not until the mechanical separator, introduced in 1885, and the Babcock test, invented in 1890, made quick, efficient separation and equitable payment for milk or cream possible that creamery butter making took rapid strides forward. In the last 20 years of the nineteenth century creamery-butter production increased fourteen fold.

Although most butter was made in Eastern states prior to the introduction of factory methods, creamery production has developed most rapidly in the Middle Western states. The growth of market-milk produc-

[1] Harry C. Trelogan, Ph.D., Assistant to the Administrator, Agricultural Research Administration, U. S. Dept. of Agr., contributed this chapter.

tion around the heavily populated industrial centers of the East has gradually replaced butter production in that section. A large part of the butter production in the New England and South Atlantic states is still farm butter. Creamery production has advanced consistently along the northern fringe of the corn belt, where the growing season is short and gently rolling land provides abundant grass pastures and sufficient home-grown feeds to support medium-sized dairy herds. The distance to city markets makes a product of high specific value imperative in this territory if it is to be produced on a commercial scale. As indicated in the following table, three states, Minnesota, Iowa, and Wisconsin, produced more than 40 per cent of the butter output in 1947. Minnesota and Iowa are outstanding among the butter producing states with an annual production of more than 200 million pounds each. However, the ten states listed in this table are the prominent butter states, manufacturing nearly three-fourths of the total output. The distribution of butter production in all states for 1932 is presented graphically in Figure 13.

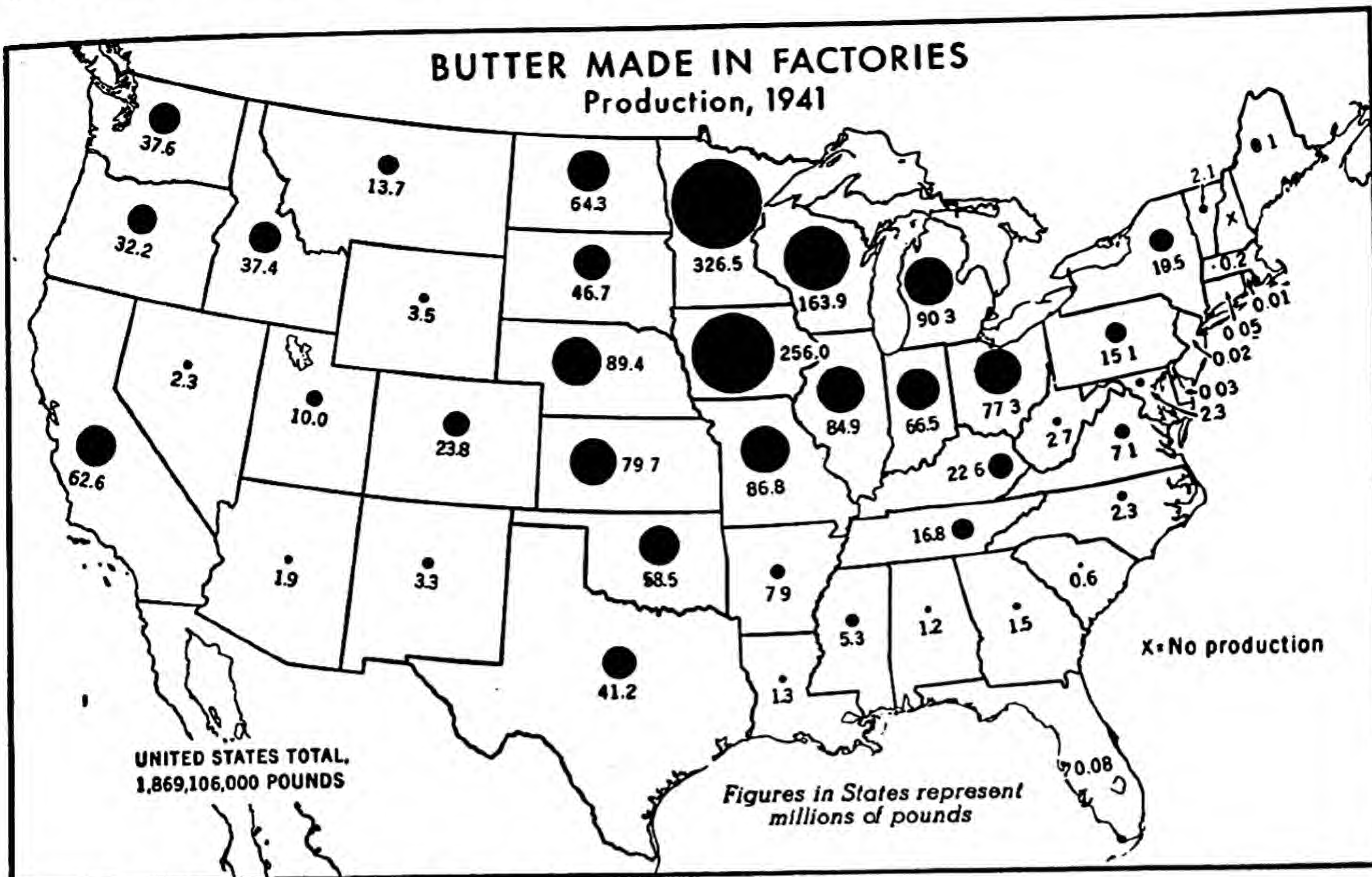
TEN LEADING STATES IN CREAMERY BUTTER PRODUCTION, 1947 [1]

State	Pounds of Butter	Per Cent of U. S. Production	Cumulative Per Cent
	Thousands		
Minnesota	243,874	18.3	18.3
Iowa	209,145	15.7	34.0
Wisconsin	115,710	8.7	42.7
Nebraska	79,003	6.0	48.7
Missouri	63,804	4.8	53.5
Illinois	59,246	4.5	58.0
Ohio	55,767	4.2	62.2
Kansas	51,001	3.8	66.0
North Dakota	49,525	3.7	69.7
Michigan	47,930	3.6	73.3
Total	975,005	73.3	—
U. S. Total	1,329,678	100.0	100.0

TYPES OF CREAMERIES

Creameries may be classified according to their means of procuring cream into local and centralizer types. Local creameries become established in regions where the cow population is dense enough to supply them with cream from a relatively small area. Farmers frequently make daily deliveries of cream to these plants, where it is first weighed, graded, and tested, and then pasteurized and churned. Low assembly costs and high quality raw materials give creameries of this type a distinct advantage in such regions. Butter makers are able to keep in close contact with the creamery patrons and influence them to deliver high quality cream in a sweet or only slightly sour condition. They are also able to make the butter

[1] Bureau of Agricultural Economics, U. S. Dept. Agr.



U. S. Dept. Agr., Bureau of Agricultural Economics

Fig. 13. Creamery-butter production in 1941 is shown in this chart.

promptly and to give it their close attention; this results in fine workmanship in the manufacturing process. Although local creameries became established in places where farmers could conveniently haul cream to them, the development of motor vehicles and good farm-to-market roads has permitted them to expand by taking in patrons from a wider territory. This tendency toward expansion has developed further with the introduction of truck routes for gathering cream from distant farms, and has helped these creameries obtain the lower unit costs which accompany large-scale production. Recently there has been a marked trend toward the establishment of whole-milk creameries which are designed to manufacture skim-milk products as well as butter. Because of fuller utilization of milk by the creamery, farmers usually obtain a greater cash return on their product from this type of operation.

Centralizer creameries are located at convenient transportation centers so that they can receive cream from a very large territory. The cream is obtained by direct railroad shipment from the farmers or through cream stations located in rural communities which accumulate cream for shipment, and in some cases with truck routes picking up cream at farms. These creameries, which are designed to handle large quantities of cream delivered from farmers at infrequent and irregular intervals, are best adapted to those areas where the cow population is sparse and rail transportation is available. Although they must contend with high costs of assembly and possible deterioration of cream in transit, they obtain

the advantages of large-scale production, reflected in lower unit manufacturing costs, more standardized products, and favorable sales outlets.

CO-OPERATIVE CREAMERIES

A distinctive feature of the butter industry is the large number of co-operative creameries engaged in production. It is estimated that about 40 per cent of the butter was made in more than 1,400 co-operative creameries in 1941. These co-operatives are mostly of the local creamery type and are most prevalent in the Northwest. Four-fifths of them are located in Minnesota, Iowa, and Wisconsin. In Minnesota more than three-fifths of all the creameries are co-operatives. The popularity of co-operative enterprise among creameries came early in their development. In the Northwest the immigrant farmers, largely of Scandinavian origin, were co-operative minded and banded together to start the first creameries in that area. Relatively little capital was needed for their establishment, and with encouragement from agricultural leaders and creamery equipment sales promoters the spread of co-operatives among rural communities was rapid and successful where the milk available in the surrounding area was sufficient to support them.

Butter co-operatives are producer co-operatives, inasmuch as the patrons own them and receive the benefits from them. Accumulations of earnings in excess of ordinary expenses are disposed of in any of three ways: (1) in a higher current payment to patrons for their butterfat, (2) as patronage dividends or (3) held as capital surpluses. The co-operatives are usually incorporated; each member holds a limited amount of stock, which yields a conservative dividend. Aside from ownership, the principal difference between the co-operatives and the other business organizations manufacturing butter is the method of paying for butterfat. Co-operatives are ordinarily operated on a pooling basis, with each month's deliveries constituting a pool. That is, receipts from sales of butter produced within a month are pooled, and the net proceeds, after operating expenses are deducted, are distributed among the patrons according to the amount of butterfat each one delivered during the month. Such a distribution is generally delayed until the butter is sold; this means that co-operatives defer payment for their cream as much as a month after they have received it. Semimonthly settlements are often employed to increase the frequency of payment.

Privately operated creameries ordinarily buy cream from farmers at a stated price which is based upon current market quotations for butter plus a fixed differential for each pound of butterfat. In contrast with co-operatives, they are operated for profit, and payment for cream is made at the time of delivery or at convenient regular intervals agreed upon by the operators and patrons. Local creameries are generally organized as sole proprietorships or partnerships, but centralizer creameries are commonly operated as branch plants of large companies which are frequently subsidiaries of nationally known food products corporations.

BUTTERFAT PRICES

Regardless of the type of creamery or the method of payment employed, prices received by patrons for butterfat depend upon the same underlying factors. The main factors are: (1) prices obtained by the creamery for its butter, (2) the cost of manufacturing butter, and (3) the overrun secured. The price obtained for butter is directly related to the grade of butter that is marketed, and the grade in turn is influenced by the quality of the cream received by the creamery and the ability of the butter maker. The markets available and the sales outlets used by the creamery also have an effect upon the price that can be obtained for the butter. The manufacturing cost which is reflected in a creamery's operating margin is affected by wage, interest, and supply costs and the volume of production of the creamery.

Much confusion is encountered with the term overrun; therefore, a careful explanation of it is needed in order to understand its relation to the price paid for butterfat by any creamery. In the first place a distinction must be made between composition overrun and "book" or "operating" overrun. Composition overrun is the amount of butter produced in excess of the amount of butterfat used in manufacture. It includes the water, curd, and salt constituents of butter, and its volume depends upon the composition control exercised in the manufacturing process. Since the law requires that butter contain at least 80 per cent butterfat a creamery cannot legally obtain more than 25 per cent of its butter from composition overrun. In practice, a butter maker usually attempts to make butter containing 80.5 per cent butterfat in order to have a margin of safety above the legal standard, and, since some butterfat is unavoidably lost in processing, a composition overrun of more than 22 per cent can hardly be expected by any butter maker.

The "book" or "operating" overrun is the amount of butter made in excess of the amount of butterfat recorded on the books as purchased for butter production. In weighing and testing cream that comes to a creamery from patrons it is common practice to weigh to the nearest full pound and to test to the nearest half per cent of butterfat. Fractions of pounds and small fractions of per cent are dropped and are not recorded on the books of the creamery as purchased. Under typical local creamery conditions the butterfat gained in this way offsets the fat losses experienced in manufacture and brings the overrun figure which is computed by the bookkeeper up to nearly 24 per cent. Under circumstances where a creamery receives an unusually large number of small shipments of cream it is possible for this "operating" overrun to exceed 26 per cent.

Composition overrun is computed for purposes of technical control, and "operating" overrun is computed most frequently for creamery business analyses. Although the "operating" overrun is dependent upon the composition overrun, it bears a more direct relationship to the price paid for butterfat because it is more inclusive. Therefore it is the operating overrun which is cited as a factor affecting butterfat price.

The higher the "operating" overrun obtained, the higher the price a creamery can afford to pay for butterfat. This must not be misinterpreted to mean that a higher operating overrun indicates a higher net return to all patrons. Farmers often use the butterfat price as the sole basis for selecting the creamery they will patronize and there is a temptation for a creamery manager to augment his price by short weighing his patrons to secure a higher operating overrun. No advantage accrues to the patrons from such manipulations. Unfortunately, too, the efficiency of a butter maker is often judged on the basis of the operating overrun reported by his creamery. Actually the composition overrun is the more accurate measure of his efficiency, and higher composition overruns yield greater net returns to patrons.

The inter-relationship between the three factors affecting the price of butterfat is such that the price of butterfat may be either above or below the price of butter. As the price of butter rises, so, too, does the value of the overrun. But the total expense involved in obtaining cream, converting it into butter, sending butter to market, and selling it on the market does not necessarily change. When the price of butter rises to the point where the value of the overrun exceeds the total expense incurred, a creamery can pay a higher price for a pound of butterfat than it receives for a pound of butter. For example, if it is assumed that a creamery obtains 24 per cent operating overrun and has a total expense of ten cents per pound of butterfat, at any time the price of butter rises above 42 cents the creamery can afford to pay a higher price for a pound of butterfat than it receives for a pound of butter. However, if the price of butter goes below 42 cents and the costs remain the same, the creamery must pay less for each pound of butterfat than it receives for butter as shown by the following calculations.

Butter Price Per Pound	+	Value of Operating Overrun	−	Expense Per Pound of Butterfat	=	Net Return Per Pound of Butterfat
Cents		*Cents*		*Cents*		*Cents*
42	+	(42 × .24)	−	10	=	42.08
40	+	(40 × .24)	−	10	=	39.60

Apparently the feeling once prevailed that the overrun belonged to the creamery to defray its expenses. Or, in other words, the price a creamery paid for butterfat should coincide with the price it received for butter. There is no justification for such a belief. The example illustrates clearly that a co-operative, which distributes currently the net proceeds obtained from the sale of butter in each pool period to its patrons, cannot operate on such a basis.

MARKETING OF BUTTER

Butter is ordinarily packed in bulk containers at creameries and shipped to central markets, where various arrangements are made for its sale. The trend from the use of wooden tubs containing 63 to 64 pounds of

butter to less expensive containers made of fiber or paper was accelerated by the war. The greater part of the butter supply is now shipped to market in fiber boxes of about 60 pounds, except on the West Coast where the 68 pound wooden box has been largely replaced by a fiber box of the same size. In the early days commission men handled the butter on the market for the creamery management, selling it to wholesale dealers or jobbers at the best price obtainable and charging a commission for their services. This method of selling butter was unsatisfactory because creameries desired to know more about how much they were going to receive before butter was shipped, and wholesale dealers wanted to be sure of a supply of butter for their regular trade. Therefore, commission men, as such, have been almost entirely eliminated by an arrangement whereby wholesale dealers contact the creameries directly, contracting to accept all butter at a price bearing a specified relationship to current market quotations on day of arrival. Wholesale dealers who receive butter in this way resell it to jobbers and retail distributors. Their service may include storing the butter until it is needed and packaging it in suitable forms, such as pound or quarter pound prints and rolls; however, some creameries package the butter before it is shipped. The larger chain store systems have established butter departments to buy butter directly from creameries for distribution through their own stores. Here the several marketing functions of assembly, storage, and distribution are performed by one organization. These methods of selling butter are best adapted to the needs of independent creameries that cannot afford to establish their own marketing facilities for the small volume of butter which they make.

Centralizer creameries usually sell butter under their own brands in printed packages ready for retail distribution. When their volume is sufficiently large they perform many of the marketing functions themselves. When they do their own advertising and distributing they eliminate the need for wholesalers and jobbers in handling their products. This is especially true when centralizers are operated by large food products distributors who deliver butter along with meat or other dairy and poultry products, using the same marketing facilities for all of them. Under such conditions they are able to establish direct, dependable market outlets for the butter.

In order to secure some of the marketing advantages enjoyed by larger creamery operators, a number of local co-operative creameries have joined together to form marketing organizations designed to handle their sales problems for them. The principal function of these marketing associations is to find markets for all the butter supplied by co-operatives affiliated with them; this they attempt to do by dealing directly with butter distributors in distant markets. Their work involves grading and packaging the butter, establishing brands, advertising, and sometimes wholesale distribution of their products. In addition, these marketing associations aid member co-operatives by purchasing supplies and equipment for them, by concentrating butter for carlot shipment, and by handling other dairy and poultry products for them. They have also brought greater net returns

to the farmers by improving the quality of butter produced in the creameries. This quality improvement has been stimulated by technical assistance furnished to butter makers and by the use of state and federal inspection services for grading butter so that it can be bought and sold on a quality basis.

A trend away from central market selling of butter has been apparent for some time. Following the lead set by the co-operative marketing associations, large butter buyers have located receiving plants closer to the supply areas. Advantages gained from this type of operation include reduced transportation costs, lower labor and supply costs, and closer supervision of production.

BUTTER STORAGE

Prior to the development of adequate cold-storage facilities the price of butter fluctuated over a wide range each year, owing to the fact that production was subject to marked seasonal fluctuations while consumption was relatively stable. Prices reached a low point in the spring months of heavy production and a high point in the fall and winter when supplies were short. To take advantage of these price changes butter dealers began, as soon as cold storage was available, to store butter in the spring and summer for sale in the fall and winter. Well over 100 million pounds of butter are usually put into storage each year during the months of May, June, July, and August, and sold from September to April. Since small creameries do not maintain sufficient cold storage space and usually do not have enough capital to finance storage beyond their routine needs in manufacturing and shipping, most butter carried over from one season to another is stored by butter dealers in their own plants or in warehouses located near the large markets. This is a speculative operation because of the price uncertainties involved and is, therefore, outside the scope of creamery operations, especially in the case of co-operative creameries. In the long run average butter prices must vary enough from the season of heavy production to the season of low production to cover costs of warehousing and losses incurred from butter shrinkage and quality depreciation in storage, or dealers will find it unprofitable to handle these operations.

BUTTER PRICE

In many respects the butter price is the most important of all dairy prices because of the fact that milk not needed for other dairy products tends to find its way into the butter market. In other words, butter, because it is a relatively stable product, easily made and readily salable, is the product which tends to absorb all excess milk. It means, too, that any milk used for other products must bring as great a return as milk going into butter or it will be used for butter instead. In view of this fundamental relationship between butter and other dairy products, many milk-product prices are computed on the basis of the price of butter. For

this reason, the methods by which the butter market quotations are arrived at are of interest to every dairy student.

The most important butter exchanges are located in New York, Chicago, and San Francisco, where butter dealers congregate for the purpose of buying and selling on the open market. Call boards are operated to record publicly the bids and offers for butter on these exchanges, and the transactions that take place aid in the determination of a market quotation. Daily butter market quotations are determined by experienced market reporters working for private publishers of these quotations and prices are reported by representatives of the market news service of the United States Department of Agriculture who analyze and "feel out" the market each morning, taking into account general market conditions along with the call-board prices. Although a relatively small proportion of the butter is bought and sold on these cash markets, which operate much like an auction, the prices so determined are basic for most of the industry because they are considered to be sensitive to the forces of supply and demand throughout the market.

In addition to the cash butter market a futures market is conducted by the Chicago Mercantile Exchange for the purpose of permitting butter dealers to hedge their storage operations by shifting the risk of price fluctuations to market speculators. This is accomplished by selling butter contracts on the futures market at the time the butter is bought for storage and then buying back the contracts at the time the butter is actually sold, or by delivering butter to fulfill the contract at the time it becomes due.

Butter is not a perfectly uniform commodity. The extensive use of factory production methods has made great strides in adapting it to a large-scale marketing system. Standardization of the product resulting from the establishment of minimum requirements of butterfat content and the adoption of market grades for measuring its quality attributes, especially those pertaining to taste, have also facilitated its exchange and rendered butter-market quotations more useful. Nevertheless, variations in other characteristics such as color, salt content, and keeping quality between lots of butter within a grade give rise to definite trade preferences for butter coming from particular creameries. These, together with variations in the butter containers and in the services accompanying wholesale butter transactions, account for the almost universal practice of dealers paying price differentials above or below the central market exchange quotations for butter bought directly from creameries.

A trend toward direct marketing of butter has resulted in a constantly diminishing proportion of the butter being traded in the central market exchanges, and a greater proportion being sold at premiums above the quotations fixed on the exchanges. Because of these circumstances and the occurrence of rapid short-time price changes of inexplicable magnitudes, the adequacy of the present butter-pricing mechanism has been subject to criticism.

Although the majority of butter today is handled by large integrated marketing organizations, such as dairy products corporations, meat pack-

ers, chain stores, and co-operative sales agencies that are equipped to take butter directly from the manufacturer and distribute it to retail stores or consumers all over the nation, there is still a definite need for butter market exchanges where these distributors as well as the dealers who act as wholesalers and jobbers can sell butter not needed for their established outlets and buy butter to offset occasional shortages. Only so long as the volume of such sales is sufficient to adequately reflect supply and demand conditions, is the use of prices arrived at on the exchanges as a basis for market values justified.

Chapter 6

ECONOMICS OF THE CHEESE INDUSTRY[1]

LOGICALLY FOLLOWING MARKET MILK AND BUTTER IN THE SCHEME OF dairy products is the cheese industry, which absorbs the next largest amount of milk. While cheese has been made for centuries and the industry is of major importance in some countries, it holds a less pretentious but, nevertheless, substantial position in the United States. Although relatively few farmers produce milk for cheese making, the interrelationship of dairy products, with milk as the common raw material, makes the prosperity of this industry of interest to every dairy farmer.

LOCATION OF THE INDUSTRY

The cheese industry has the unique distinction of being one of the most concentrated industries in the country, from the point of view of manufacturing area. By far the most of it is located in Wisconsin, where 45 per cent of the American Cheddar cheese, 86 per cent of the brick, 66 per cent of the Swiss, 51 per cent of the Limburger, and 91 per cent of the Munster cheese, and 61 per cent of the Italian varieties of cheese were made in 1945. Figures 14 and 15 illustrate how the factories are segregated into fairly compact, well-defined areas in Wisconsin—an economically significant characteristic of the industry.

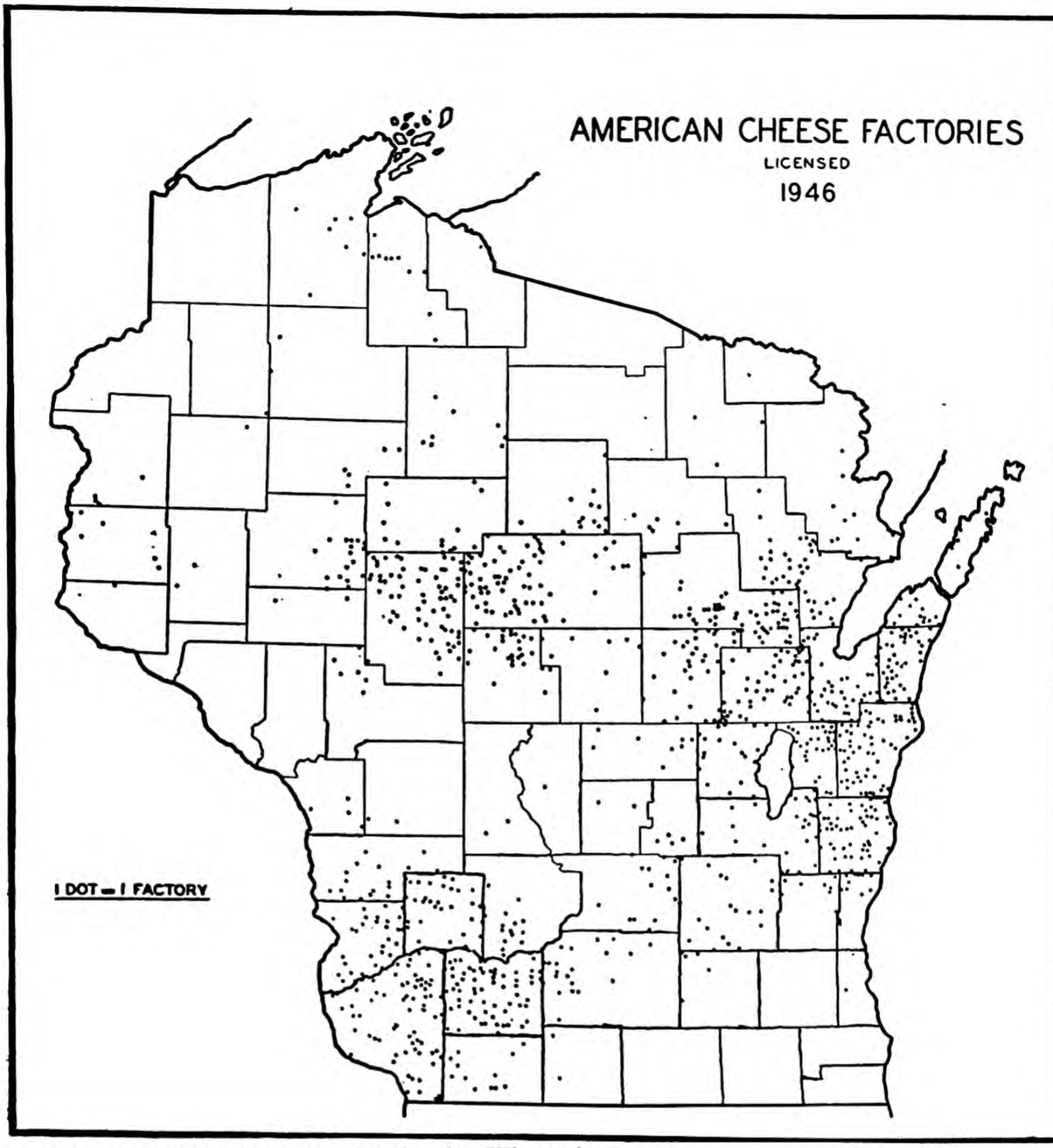
Cheese production began in this country about 1795 and was confined to farms until about the middle of the last century, when farm production reached its highest peak. In 1851 the first cheese factory was established in Oneida County, New York, inaugurating the shift to factory production which is now practically complete. The following table traces the change from farm to factory production in census years.

CHEESE MADE ON FARMS AND IN FACTORIES IN THE UNITED STATES, 1849 TO 1929
(Million Pounds)

Year	Farm Cheese	Factory Cheese	All Cheese
1849	105.5	——	105.5
1859	103.7	——	103.7
1869	53.5	109.4	162.9
1879	27.2	215.9	243.2
1889	18.7	238.0	256.7
1899	16.4	282.0	298.3
1909	9.4	311.1	320.5
1919	6.3	473.6	479.9
1929	——	483.9 *	483.9

* Cottage cheese was included in census figures until 1919.

[1] Harry C. Trelogan, Ph.D., Assistant to the Administrator, Agricultural Research Administration, U. S. Dept. of Agr., contributed this chapter.



Federal-State Crop Reporting Service for Wisconsin

Fig. 14. American cheese factories in Wisconsin are largely located in three important areas as shown above.

Accompanying the farm to factory shift was a general western movement in the cheese-producing area. Prior to 1870 New York was considered the center of cheese production, but with the gradual encroachment of the market-milk industry in that area the cheese industry moved toward Wisconsin, following a course just south of the Great Lakes. As is indicated in Figure 16, the Lake states are still among the important cheese producing states. Production, particularly of Cheddar cheese, is on the decline in New York, but it is on the incline in the other Lake states. A secondary cheese-producing area has also been established in the West Coast region, centering in Oregon. Recently there has been a swing toward cheese production in several Southern states where dairying is taking a

firmer hold and in some market milk areas where milk surpluses are being diverted to cheese.

These latter trends have caused cheese production to increase more rapidly in states other than Wisconsin, which in 1923 produced 73 per cent of the Cheddar cheese, compared with 45 per cent in 1947. Although Wisconsin's pre-eminence has been reduced, it has not been seriously threatened as indicated by the table below showing the five states leading in cheese production in 1947. Several factors responsible for the location of the cheese industry in Wisconsin include: (1) density of cow population, (2) nationality of the people, and (3) natural conditions.

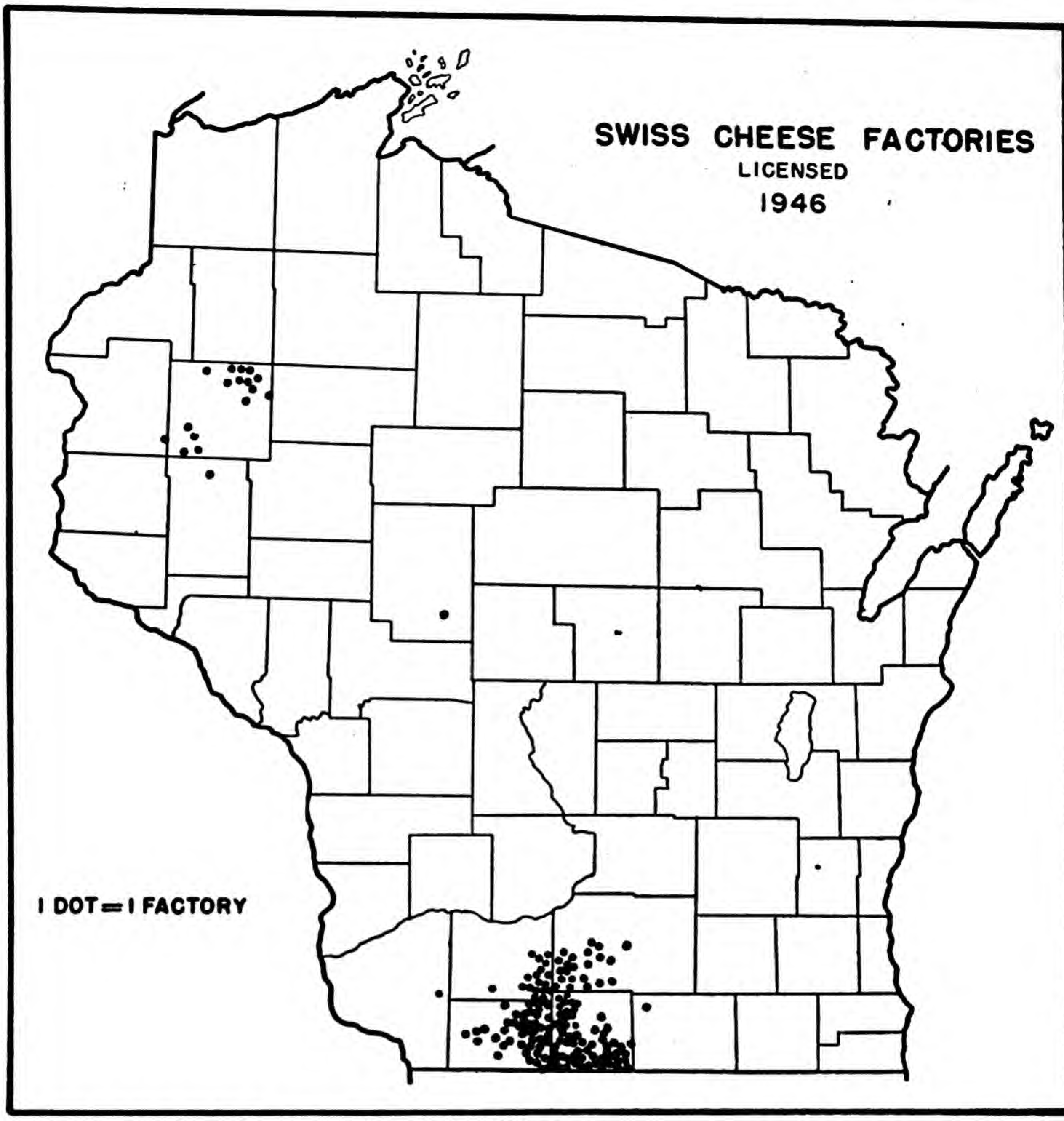
FIVE LEADING STATES IN PRODUCTION OF CHEESE, 1947 [1]

State	Pounds Produced	Per Cent of U.S. Production
	Thousands	
Wisconsin	535,873	45.5
Illinois	86,864	7.4
New York	71,043	6.0
Minnesota	58,949	5.0
Missouri	58,738	5.0
Total	811,467	68.9
U. S. production	1,177,669	100.0

Dense cow population. A dense cow population is required for cheese-producing areas because the milk must be delivered fresh and sweet to cheese factories. In the past a distance of five miles was generally considered the limit of practicability for hauling milk to the small cheese factories, which were usually supported by 15 to 35 patrons living within a radius of one or two miles of the factory. For such a factory system Wisconsin, with twice as many cows in proportion to the crop acreage as any other state, presented ideal conditions. Recent trends in cheese production have been toward larger cheese factories. Improved roads and truck transportation have permitted plants to draw milk from wider areas and have made the operation of cheese factories practical in regions formerly unsuited for cheese production. Consequently, progress in this direction has been most rapid outside of Wisconsin where new factories have been started. Within Wisconsin the trend has been marked by a tendency to consolidate small factories into larger, more efficient plants, and, with the advantage of the dense cow population, this state promises to remain the stronghold of the cheese industry.

Nationality of the people. Modern cheese making traces back to widely separated localities in Europe where different types of cheese, characteristic of the localities, have been made for centuries. As cheese became an article of commerce, different kinds became identified by names of the geographic locations of their origin. Since methods of making and handling these cheeses were intimately related to the climatic and

[1] Source: Bureau of Agricultural Economics, U. S. Dept. Agr.



Federal-State Crop Reporting Service for Wisconsin

Fig. 15. Swiss cheese factories, like other foreign-type cheese factories in Wisconsin, tend to be concentrated in particular areas.

local conditions of their points of origin, cheese making became an art passed down from one generation to another by the inhabitants. The cheese industry in this country originated largely from a series of transplantations by immigrants from these areas who sought to evade the pressing economic circumstances of the Old World by finding new homes where they could carry on their accustomed pursuits. Wisconsin has been the settling place for many of these people, who congregated in relatively small areas and began to make cheese similar to the kind they made in the old country. Even today the majority of cheese makers in foreign-type cheese factories are direct descendants of European cheese makers.

Natural conditions. The natural conditions of Wisconsin are well adapted to the needs of the cheese industry. The abundance of cold water and the cool nights are desirable natural factors for inexpensive operation

of cheese factories. In addition, Wisconsin has the advantage of being situated in an area that is better suited for dairying than for any other kind of agricultural enterprise. In these respects it approximates the conditions existing in European countries where cheese was developed, and for this reason attracted the immigrant cheese makers who had much to do with the settling of the industry in that state.

However, the natural conditions of the area and the nationality of the people are becoming smaller factors in limiting the spread of the cheese industry. This is true for several reasons. In the first place, most of the domestic cheese made today is a distinctly American variety of English Cheddar cheese. Second, cheese making is now being developed on a scientific basis, and, as more is learned about the bacteriology and chemistry involved in cheese making, a fund of technical knowledge is becoming more essential to the cheese maker than just practical experience. This knowledge, together with the application of modern refrigeration and humidification to overcome inferior natural conditions, is being used to adapt cheese factories to areas where they were previously impractical.

CHEESE FACTORIES

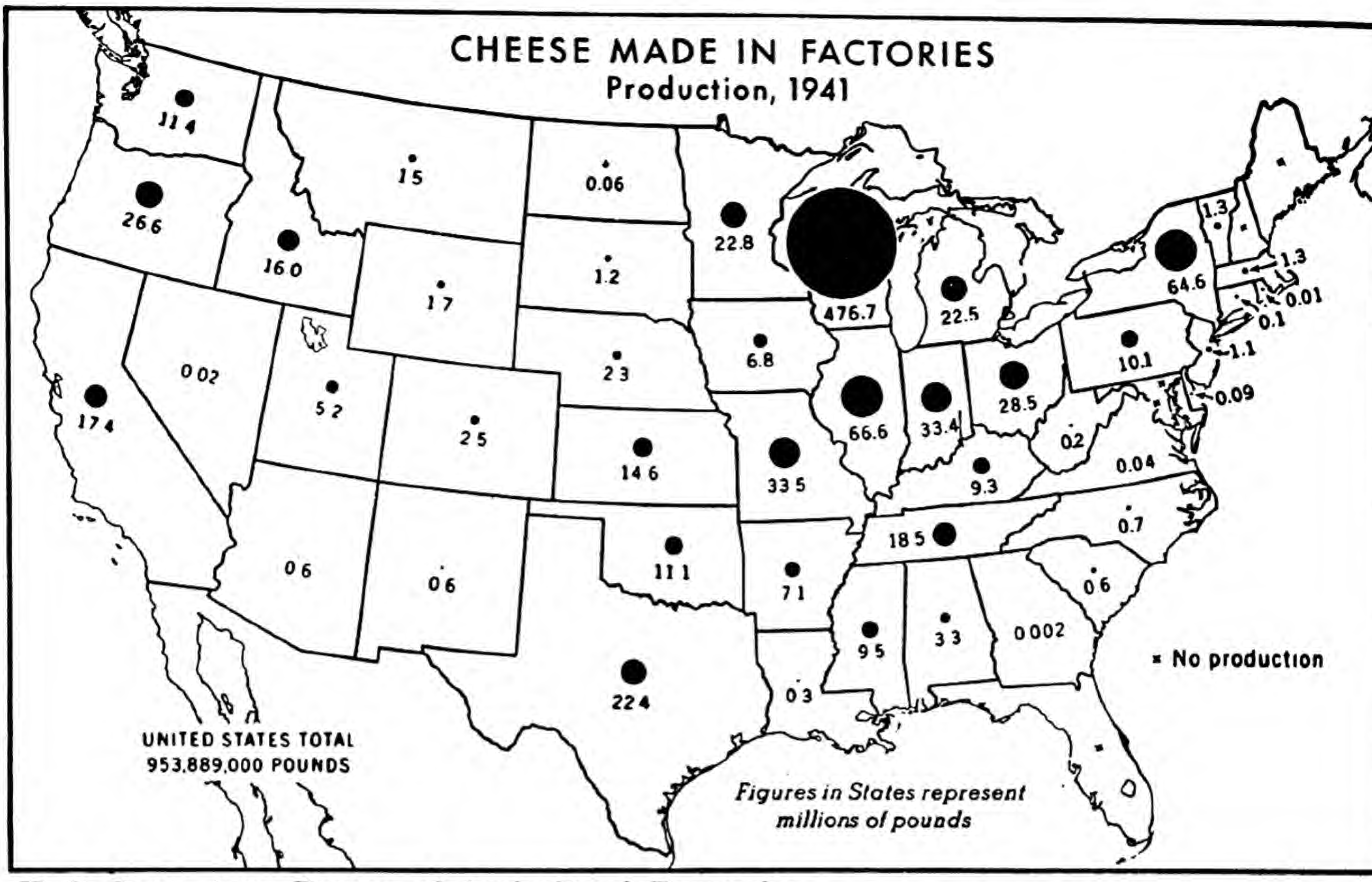
In 1947 there were about 2,400 cheese factories in the United States. This represents a significant reduction in number since 1919, when 3,500 were in operation. The decline is largely accounted for by the increase in size of cheese factories. Nevertheless, the prevailing type of cheese plant is still the small crossroads factory requiring a small capital outlay for building and equipment.

Since the patrons are usually located near the plants, cheese factories are quite well adapted to the co-operative type of management. About one-fourth of the factories are owned and operated by co-operative associations. These co-operative factories ordinarily operate on a butterfat pooling system, making monthly or semimonthly payments to the members. The capital stock is owned by the member-patrons, who seldom have any formal delivery contracts with the factory. A much higher proportion of the foreign-type cheese factories than of the American cheese factories are co-operatively owned.

Privately operated cheese factories are usually owned by the cheese makers or are operated as one of several factories organized in a chain. These factories usually pay for milk on a butterfat basis, with the price bearing a definite relationship to a current call board price of cheese.

LOCATION OF MARKETS

Since cheese is a comparatively bulky article, it is produced fairly close to consumption centers, but it must be manufactured close to the raw product. For these reasons cheese production tends to fit into the zones of milk production between the market-milk area and the butter-producing area. Wisconsin, located between the large Chicago and Eastern milk markets and the Minnesota butter areas, is ideally situated for cheese production and marketing.



U. S. Dept. Agr., Bureau of Agricultural Economics

Fig. 16. Cheese production in 1941 is shown here.

The concentration of cheese factories in Wisconsin also has several marketing advantages: the cheese can be assembled more easily for shipment and the cost of transportation to warehouses is less where the producing area is restricted. The majority of Wisconsin cheese factories sell their output to assemblers and processing plants located at convenient concentration points, where the product is waxed, cured, graded, and packed. Cheese assemblers sell to wholesale and retail distributors in all parts of the country, including some of the small towns where the cheese was originally made. This may look like wasted effort, but it is really efficient division of labor and yields the advantages of specialization. The market for cheese is so restricted in these small towns that the work of storing cheese for an adequate period and grading it on a uniform basis for the wholesale trade cannot be efficiently done there. When cheese from a number of small neighboring towns can be concentrated for expert grading and diversion to markets where it is in demand, a greater return is realized by the producers. The principal markets are, therefore, located in such Wisconsin towns as Plymouth, Green Bay, and Beaver Dam, and in Chicago and New York.

MARKETING CHEESE

Many co-operative cheese factories are affiliated with overhead marketing organizations which perform warehousing, grading, and advertising functions and handle the development of sales outlets for them. These marketing associations are similar to those handling butter, often being

one and the same, attempting to standardize both products for a more direct-marketing system.

Some cheese factories are controlled by large cheese processing corporations that market their own products. But many more belong to the group of independent factories that contract with large cheese dealers to ship their entire output to them. Other privately owned cheese factories sell their cheese to buyers in nearby markets who often send out trucks to gather the cheese at the factories.

Most of the trading in cheese is based upon market-price quotations determined in somewhat the same manner as the butter-price quotations. To assist in the determination of cheese prices call boards are conducted, the most important of which is located at Plymouth, Wisconsin. Under the call-board system sellers list on a blackboard the quantity, quality, and price of the cheese they have to offer for sale, and buyers place their bids for this cheese in allotted spaces opposite the sellers' listings. For a specified time after all bids are posted, the buyers and sellers are given an opportunity to alter their prices if offers and bids do not coincide, and sellers may withdraw their offers if the bids are not satisfactory. When the bids and offers do coincide trades are consummated, and the price paid is a matter of public record. After the call is concluded market reporters consider the trades that have been made and related market information in determining price quotations for the day. Since the cheese call boards are usually conducted only once a week, prices established by them tend to be influential or provide benchmarks for trading for a week at a time.

MERCHANDISING CHEESE

Natural cheese has always been difficult to handle on the retail market because it arrived in sizes and packages inconvenient for the consumers. It has also been subject to criticism for lack of standardization and poor grading. Consequently, the American housewife has been slow to adopt cheese as a daily food staple in the home and it has tended to be consumed more as a specialty food by people who have been able to obtain cheese that satisfied their particular tastes. While some changes in natural cheese production, such as the introduction of smaller sizes and pasteurization, have helped to meet these objections, the development of process cheeses has done much more to overcome merchandising difficulties.

Process cheese is a reconstituted, blended product that is made by combining a number of natural cheeses of different grades and subjecting them to a standardized manufacturing procedure which results in a relatively uniform product. This product is put into small, convenient packages that appeal to the housewife. Intensive merchandising campaigns conducted by process cheese manufacturers and distributors have contributed a great deal toward the increased consumption of cheese in recent years. Many of the process cheeses are prepared as spreads or incorporated with other food products, and this also has tended to expand the market.

Soft cheeses, including cream, Neufchâtel, and cottage varieties, are very perishable products that are made and sold under entirely different

circumstances from those of the American Cheddar and foreign-type cheeses. Soft cheeses are often made as by-products in city milk plants and distributed along with milk and cream either to retail stores or directly to consumers on regular milk routes. In addition, they are made largely from surplus milk or skim milk available from market milksheds, or from ingredients made and stored during seasonal milk surpluses. For these reasons they are frequently considered more closely akin to the market-milk industry than to the cheese industry.

Chapter 7

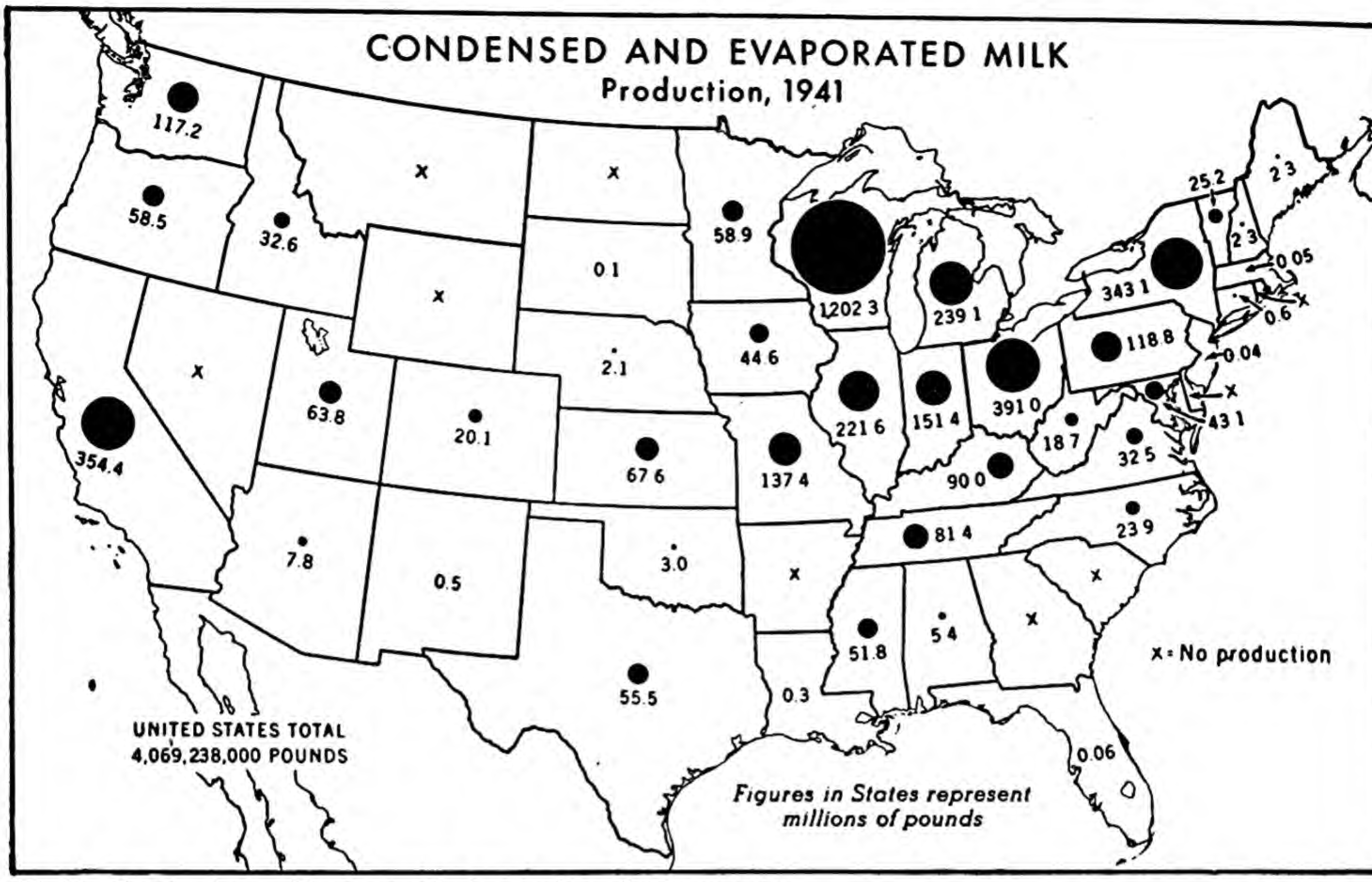
ECONOMIC PHASES OF THE CONCENTRATED MILK PRODUCTS[1]

EVER SINCE MAN BEGAN TO USE MILK AS FOOD HE HAS SOUGHT METHODS to preserve the milk so that he could consume it at his convenience. Butter and cheese are less perishable than milk and answer this purpose to some extent, but these products contain only a part of the food elements of whole milk and do not keep well at high temperatures. Since milk contains 87 per cent water, several methods of reducing the water content of milk without removing any of the food substances have been devised as means of preserving it. Dried, evaporated, and condensed milks are the products resulting when this is done. Dried milk—milk with nearly all water removed—was the first of these products to be produced, but most of the dried milk produced today is made from skim milk and is, therefore, discussed under the heading of milk by-products. Condensed and evaporated milks are made from whole milk and have a smaller proportion of water removed. Together they absorb about 6 per cent of the total milk production and represent the most important concentrated-milk products made at present. Since the concentrated-milk industries are of relatively recent origin, however, the future may find them playing a greater role in the scheme of dairy products.

The first successful method for condensing milk was invented by Gail Borden, who received a patent on his process in 1856. Production of condensed milk did not get well started until the Civil War, when the product was found to be well adapted as a food for military forces and demand for it increased tremendously. At that time condensed milk, which is sweetened with sugar to aid preservation, was the only concentrated-milk product available, but its importance today is overshadowed by unsweetened concentrated-milk products. Nevertheless, about 114 million pounds of sweetened condensed milk were packed in cans and used for infant feeding and culinary purposes in 1946, and 73 million pounds were sold in barrels for use in the preparation of candy and other manufactured foods.

A variety of other concentrated-milk products are called plain condensed milks. They are for the most part unsweetened, unsterilized, and perishable products that are sold in bulk for use in prepared foods. Even though their aggregate production exceeds 100 million pounds, they are of minor importance among dairy products, so the remainder of this discussion will be largely confined to the evaporated-milk industry, which is by far the largest of the concentrated-milk industries.

[1] Harry C. Trelogan, Ph.D., Assistant to the Administrator, Agricultural Research Administration, U. S. Dept. of Agr., contributed this chapter.



U. S. Dept. Agr., Bureau of Agricultural Economics

Fig. 17. Condensed and evaporated milk production in 1941 is pictured above.

EVAPORATED MILK

About 60 per cent of the water is removed from whole milk in the preparation of evaporated milk, which is an unsweetened product that is sterilized and packed in hermetically sealed cans to preserve it. The process for making evaporated milk was patented by John B. Meyenberg in 1884, and commercial production was started the following year at Highland, Illinois. It was not produced extensively until the needs of the military forces in the Spanish-American War stimulated its production. Subsequently, production increased steadily, reaching about 2,500 million pounds in 1940 and then increasing to a wartime peak of 3,776 million pounds in 1945. In 1946 production dropped back to around 3,000 million pounds.

Location of the industry. Evaporated-milk plants are to be found in 28 states in areas of heavy milk production. Wisconsin, with 35 plants and nearly 30 per cent of the total output in 1946, is the leading state. Ohio and California, each with about 8 per cent of the production, and Michigan and Illinois with 6 per cent each, are the other leading states. (Fig. 17.) These plants are usually located on the outskirts of large market milksheds where surplus milk can be diverted to them during the season of heavy milk production. Surplus market milk is very desirable for the manufacture of evaporated milk, since a high quality raw milk that will resist curdling at the high temperatures to which it is exposed in processing is required. Because of transportation costs for the finished product, evaporated milk plants need to be located within a reasonable distance of

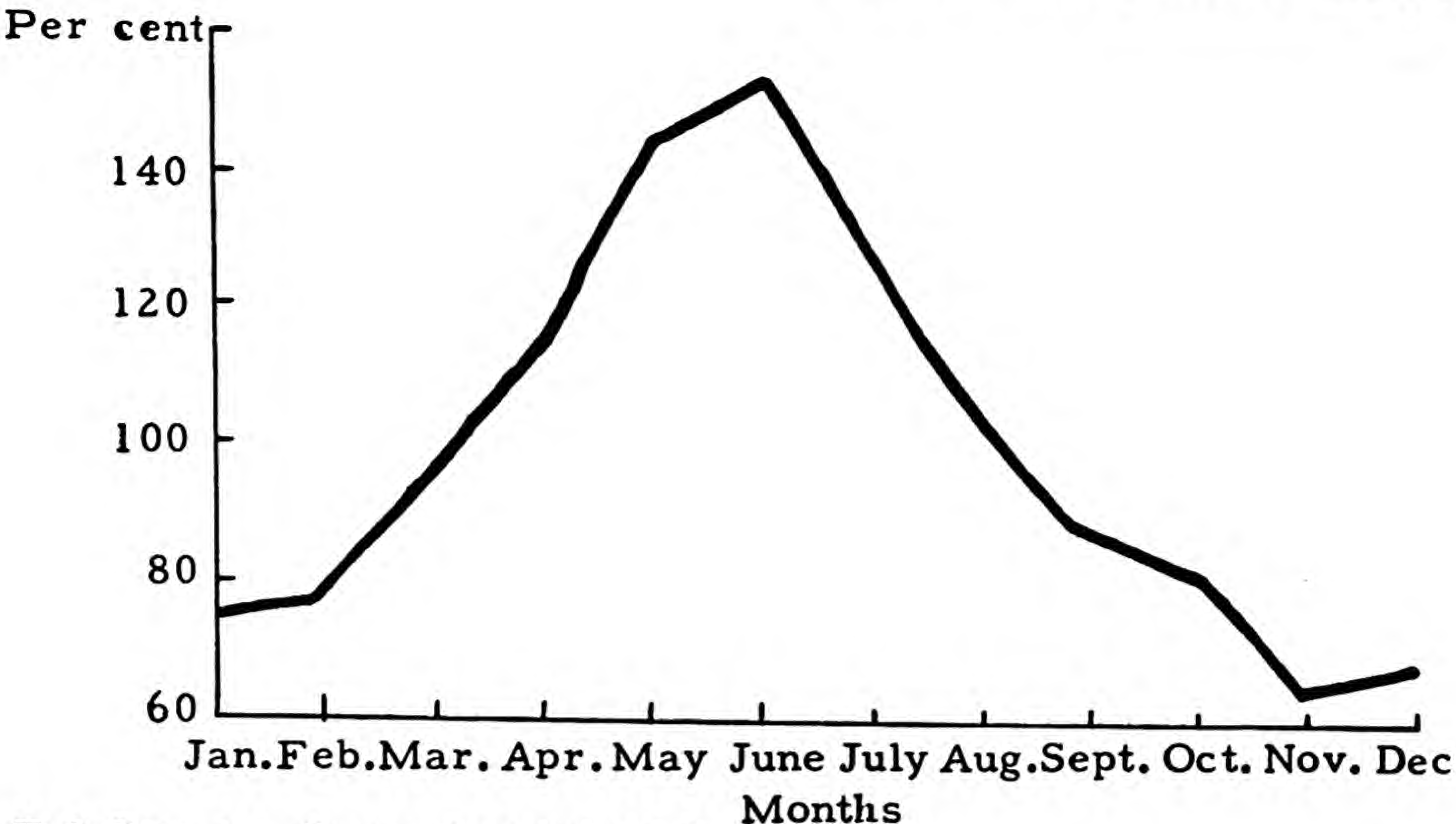
the markets. Consequently, they are to be found in every section of the country fairly close to large consuming centers.

Size of plants. A typical evaporated-milk plant handles from 150 to 175 thousand pounds of milk a day during the flush season and about half that amount during the winter season. Plants of this size are much larger than those used in the manufacture of the other dairy products, but the nature of the evaporated milk industry calls for large size factories. Expensive, specialized equipment is required to make evaporated milk, and close supervision of this equipment by well-trained men is necessary to obtain a satisfactory product. Therefore, an evaporated-milk plant entails a large investment in men and machinery, and in order to keep the costs per unit of product down, each plant must have a high production. The entire production of evaporated milk was accomplished in 142 plants during 1946. Supplementing these main evaporating plants, however, were a number of milk receiving plants, some of which were used to concentrate milk for shipment to the main factories where it was reprocessed and canned.

Type of ownership. Factories of the size and scale of evaporated-milk plants are best operated by competent corporate managements. This is true because few proprietorships or individual co-operatives have sufficient capital or the kind of management suitable to operate such large and complex business enterprises. A further deterrent is the difficulty of finding sales outlets in competition with the highly advertized brands of large-scale producers. During the war, with assured outlets to governmental agencies, co-operatives making evaporated milk increased in number from 6 in 1940 to 11 in 1945. They manufactured about 7 per cent of total production in 1946. With the exception of the 11 co-operatives, all of the 53 companies comprising the evaporated-milk industry are general corporations. About half of these companies are also engaged in the production of other concentrated milk products, such as condensed milk, condensed skim, and ice cream mix.

Milk procurement. The production of evaporated milk is highly seasonal, with over twice as large an output in the spring as in the fall. This fluctuation is caused by the normal seasonal change in raw-milk production on the farms supplying the evaporated-milk plants, and by the shift of surplus milk from the milksheds to evaporating plants in the periods of heavy production. Since evaporated milk is an imperishable product, great quantities of it can be made when milk is plentiful and stored for sale at a later time. When the evaporated-milk industry absorbs a large amount of raw milk during seasons of heavy production it has a stabilizing effect upon all dairy prices. Figure 18 shows the magnitude of the seasonal change in production, indicating the part the industry plays in absorbing or adjusting the milk supply that is put on the market.

The price paid for the raw milk delivered to evaporated-milk plants is closely related to current prices of butter and cheese. The evaporated-milk marketing agreement and license, introduced under the Agricultural Adjustment Administration and continued until 1947, illustrated this



U. S. Dept. Agr., Bureau of Agricultural Economics

Fig. 18. This graph shows the seasonal index of production of evaporated milk, 1921–1940.

point by establishing minimum prices for this milk computed according to a definite formula. It was estimated that about six times as much milk was used for butter as was used for cheese; the formula weighted these two basic prices accordingly by taking six times the butter price plus one times the cheese price and dividing by seven to obtain what was known as the combined butter and cheese value. This value was raised by 30 per cent and multiplied by the butterfat content of the raw milk to obtain the minimum price for milk that was used for evaporating. This represents a somewhat higher price than farmers obtained from the milk going into butter and cheese, because quality requirements are more stringent, because farmers supplying the evaporated-milk plants are generally located closer to the cities where costs of production tend to be higher and because there is no skim milk, whey, or buttermilk remaining for them to use as feed. In 1946 the approximately seven billion pounds of milk that were transformed into evaporated milk brought farmers well over 200 million dollars.

Sale of evaporated milk. After the milk is evaporated it is packed in cans of two sizes, containing 6 ounces and 14½ ounces, for the retail trade. These cans carry brand names so consumers can easily recognize the product on the shelves of a grocery or delicatessen. The brands that are promoted with advertising to stimulate the demand for them are called advertised brands and generally sell for slightly higher wholesale prices. Because of these brands, the sale of evaporated milk is closely identified with the manufacturers, who tend to develop their own sales organizations to wholesale the product in their principal sales territories. When the evaporated-milk manufacturer is associated with one of the nationally

known food distributing companies the product is delivered directly to the retailers along with other food products. Co-operative associations producing evaporated milk are usually affiliated with one of the co-operative sales agencies for dairy and poultry products that handle their distribution problems for them.

Annual per capita civilian sales of evaporated milk increased from about 10 pounds in 1925 to 17.4 pounds in 1940. One of the factors contributing to the consistent prewar expansion of this industry was the decline in retail prices that accompanied the growth of sales. Contrary to what might be at first concluded, this decline of retail prices was not at the expense of farmers who continued to receive prices for their milk comparable to those paid by other dairy manufacturers in the same period. Rather, it resulted from shrinkage in manufacturing margins which were cut in half during the period. Lower unit manufacturing costs derived from elimination of many spoilage losses, from benefits of large-scale production, and from general improvement in efficiency, accounted for the major part of the reduction in margins and prices. Despite greatly increased production, civilian per capita sales fell off slightly during the war owing to overseas requirements. In 1946, civilian per capita sales recovered to the point where they again exceeded 17 pounds.

Concentrated-milk products constitute the majority of exports of all dairy products in peacetime years. Evaporated milk holds the most prominent place among these exports. Because of its keeping qualities without refrigeration, it is especially well adapted for use in tropical countries, where it finds a good market.

USES OF EVAPORATED MILK

Domestically, almost all the evaporated milk is used for household purposes. It can be diluted with water and consumed in much the same way as whole milk. In the feeding of infants this practice is especially important. It is also used for cooking, and with breakfast foods and in hot beverages in place of cream. Thus it is evident that evaporated milk can and does compete with market milk and cream and tends to make the demand for those commodities more elastic. That is to say, when the prices of market milk and cream get too high in relation to evaporated-milk prices, the latter may be substituted for the former by consumers who cannot afford to pay the higher prices. Sales promotion work on the part of the Evaporated Milk Association, the industry's trade organization, has done much to popularize the product among consumers who do not require it for its keeping qualities alone. Consequently, it is accepted as a kitchen requirement, not only to replace other dairy products but also in new uses that have a tendency to augment the total demand for milk.

The nearly 50 per cent increase in evaporated-milk output during the last war was primarily for the purpose of meeting military and relief demands. The product was particularly well adapted to use under the adverse conditions encountered during military operations because of its

high nutritive qualities and ease with which it could be transported, stored, and distributed without refrigeration.

Following the war the large expansion in the infant population together with other demands has caused domestic utilization to be distinctly higher. Consequently, production has been maintained well above prewar levels.

Chapter 8

ECONOMICS OF THE ICE CREAM INDUSTRY[1]

ALTHOUGH PRECURSORS OF ICE CREAM, SUCH AS COOLED BEVERAGES, AND water ices, were known centuries ago as popular desserts they were of little economic significance because of their prohibitive costs. It was not until milk products were used as ingredients for frozen delicacies in the eighteenth century that they became of any significance whatsoever to the dairy industry. Ice cream, which consists primarily of dairy products that are mixed together, sweetened, and frozen, was first made commercially in this country in 1851 by Jacob Fussell of Baltimore. In succeeding years Fussell was able to establish plants in large Eastern cities, but the industry did not grow much until inventions of the cream separator, mechanical refrigeration, and the Babcock test made production more feasible and economical on a larger scale. The industry has experienced rapid growth since 1900, when some 30 million gallons of commercial ice cream was made. In 1946 about 645 million gallons were manufactured at wholesale and 64 million gallons at retail. This together with 15 million gallons of milk sherbets and ice milk utilized the equivalent of around 10 billion pounds of milk.

LOCATION OF THE INDUSTRY

Commercial ice cream making was started by a milk dealer who was seeking a profitable way to dispose of his surplus milk and cream. The industry has been closely associated with the milk business ever since, helping to utilize seasonal surpluses of milk and cream. Ice cream is made in cities and towns close to the ultimate consumers because it has to be maintained at low temperatures at all times. It is cheaper to transport the raw materials to a point near the consumers than it is to ship the finished product packed in ice, dry ice, or refrigerated trucks over long distances. Consequently, the ice cream industry is scattered all over the country, but it is most important in large consuming centers. The industrial states, especially in the East, are the stronghold of the industry (see Fig. 19).

Source of milk supply. Because ice cream plants are located in cities and towns along with market-milk plants and are often operated in conjunction with them, dairy products that go into ice cream usually come from the same sources of supply as market milk and cream. Sometimes health authorities require that all cream used in ice cream be obtained from the milkshed as it is defined by them, or that it pass their inspection. In such cases this cream usually carries a special classification when it is

[1] Harry C. Trelogan, Ph.D., Assistant to the Administrator, Agricultural Research Administration, U. S. Dept. of Agr., contributed this chapter.

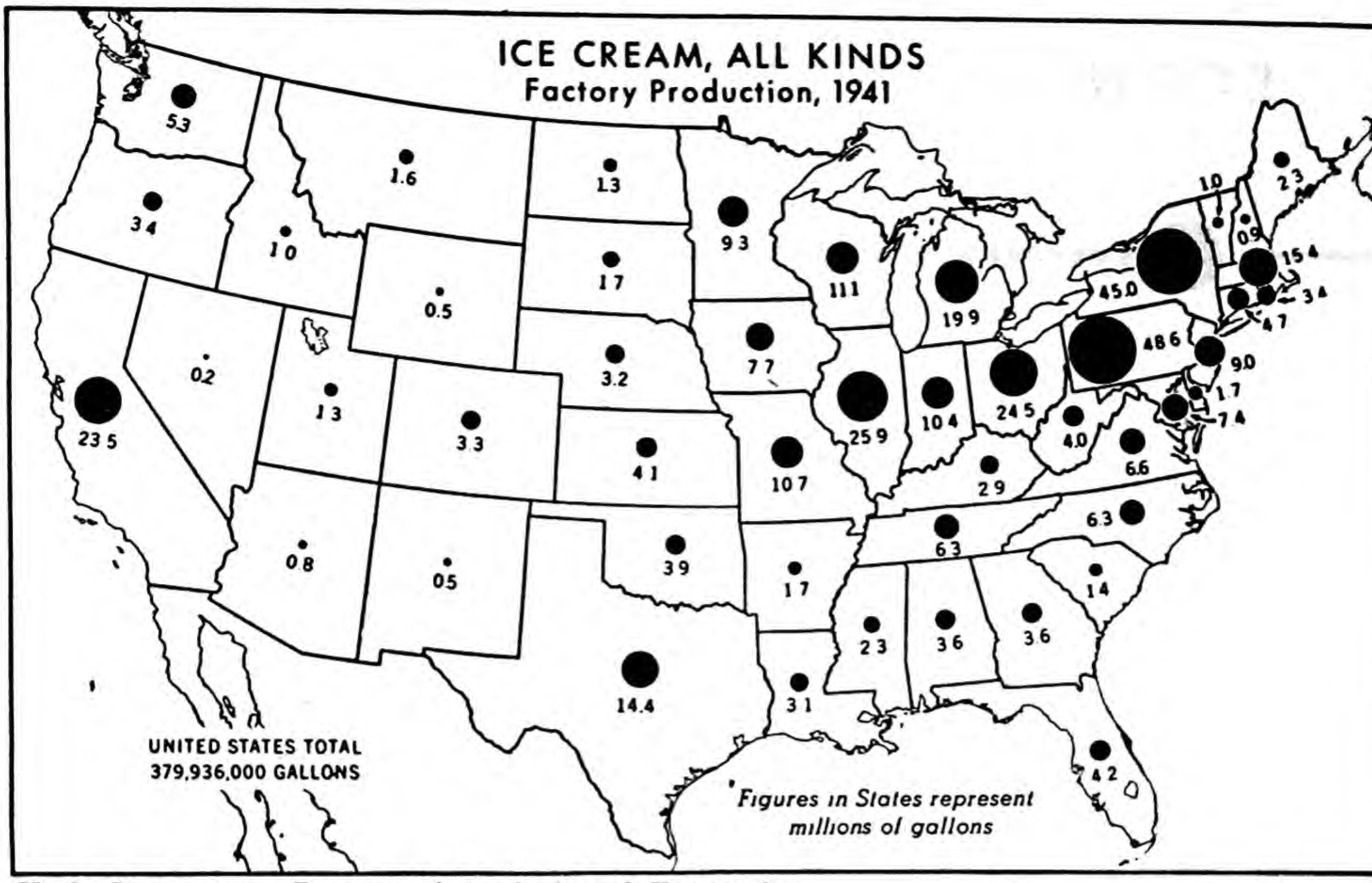


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Fig. 19. Ice cream production at wholesale by states in 1941 is shown here.

sold by producers' bargaining associations and yields a higher return than cream used for other manufacturing purposes. In markets where there are no territorial restrictions on cream used for ice cream, manufacturers use surplus milk from the milkshed during the flush season and obtain cream from outside areas when the supply is short.

Some deviation from this general pattern has occurred with the more widespread production and sale of ice cream mix. While mix prepared for wholesale or retail distribution in either fluid or dry form may be manufactured in the same plants that freeze ice cream, there is a tendency for much of it to be produced in dairy manufacturing areas rather than near consuming centers. This is especially true of dry mix preparations.

Although the year-around demand for ice cream is increasing, fortunately it is heaviest at the time of year when milk production is also high. On the average, for the last 15 years more than 50 per cent of the ice cream was produced during the warm months from May to August; therefore the use of milk for ice cream tended to relieve seasonal milk surplus problems. During periods of limited milk supplies, ice cream makers can resort to concentrated-milk products and butter as sources of butterfat and other milk solids. These products can be obtained economically from distant markets.

Plants. Most ice cream is manufactured in rather large specialized plants producing more than 500 thousand gallons a year. Nevertheless, most plants producing ice cream are small or medium-sized plants which make ice cream exclusively or in combination with other dairy products, such as market milk and butter. The total number of ice cream plants has

been slowly increasing. The following table shows the number of plants of different sizes, measured in terms of annual gallonage, in operation in 1946.

NUMBER, SIZE, AND PRODUCTION OF WHOLESALE ICE CREAM PLANTS, 1946[1]

Number of Plants	Size (Gallons)	Gallons Produced
1,362.....	Less than 50,000	27,187,651
856.....	50,000–200,000	89,603,545
401.....	200,000–500,000	125,223,487
177.....	500,000–1,000,000	124,723,642
124.....	Over 1,000,000	263,846,579
2,920.....	All plants	630,584,904

Distribution. Methods of manufacturing and selling ice cream have altered considerably in the last two decades. Formerly, nearly all mix was made and frozen in plants that distributed ice cream to independently operated retail outlets, such as drug stores, confectioneries, hotels, and restaurants. Under this system the ice cream was sold in bulk; i.e., it was sold in cans containing several gallons to retailers who repacked it in suitable containers or served it at fountains as customers called for it. This may still be regarded as the basic pattern of ice cream distribution but a large share of current production is distributed in other ways.

Among the more significant changes has been the tendency toward segregation or separation of the two basic functions in ice cream manufacture, viz., the making of mix and the freezing of ice cream. Contributory to this change has been the widespread introduction of small freezers, commonly known as counter freezers, in specialized ice cream stores or other retail outlets, such as drug stores, department stores, hotels, or confectioneries, that handle relatively large volumes of sales. Of perhaps as great importance, has been the perfection of household refrigeration permitting convenient home freezing of ice cream, and also the development of prepackaged ice cream mix for retail distribution to supply the demand for a product that can be frozen at home.

Several other innovations have tended to retard the trend away from the performance of the mix making and ice cream freezing functions in single plants, and to expedite a net increase in ice cream sales. One has been the development of specialized ice cream retail stores operated by the ice cream manufacturers who thereby distribute their ice cream production through their own retail outlets. Another has been adoption of continuous freezing operations which has made large-scale freezing of ice cream much more efficient. Accompanying this later development has been the greater emphasis placed upon distribution of prepackaged ice cream. The sale of ice cream packed in suitable retail containers has received considerable impetus with the general development of frozen foods distribution through groceries, delicatessens, and other outlets. Ice

[1] Excluding counter freezers—Bureau of Agricultural Economics, U. S. Dept. Agr.

cream has shared the benefit of these new avenues of distribution along with prepackaged fruits and vegetables, meats, fish, and other perishable products.

Peddlers are also used extensively in the distribution of ice cream products. In only a few cities do they function as wholesale distributors of ice cream to retail outlets. More commonly, they are found engaged in retail distribution handling prepackaged goods and specialty items.

Among dairy products, ice cream probably exhibits the least uniformity in methods of distribution, methods of pricing, and standards of quality. For the most part, the quality and prices of ice cream and other frozen dairy foods are determined by the manufacturers who tend to adapt them to their own system of distribution. As the ice cream industry has progressed, however, the quality of ice cream has been improved through the introduction of minimum standards and other regulative legislation that provides a greater degree of standardization. As a net result of the changes that have occurred, consumers have gained confidence in ice cream as a nutritive food product that is readily available.

FLUCTUATIONS IN PRODUCTION

Production of ice cream is subject to extreme fluctuations because of rapid changes in demand that occur under varying conditions. The outstanding and most familiar fluctuation is seasonal. The table on page 93 traces production by months for 1947 illustrating the great changes that occur from one season to another. In addition to seasonal changes, short-time fluctuations occur from day to day and week to week in response to holiday and hot weather demands.

Changes of longer duration that accompany business cycles also find ice cream particularly vulnerable because of its dependence upon the incomes of industrial workers. During the depression years following 1929 production dropped 42 per cent. On the rebound, production increased as much as 22 per cent in one year, from 1935 to 1936. And with the incidence of prosperous times in 1941, a 23 per cent increase was experienced, followed by another 19 per cent increase in 1942. War requirements for other dairy products caused ice cream production to be curtailed, but still higher levels of production and consumption were reached after the cessation of wartime controls, reaching a peak of 713,594,000 gallons in 1946.

Any industry that experiences large fluctuations in production is bound to have unutilized capacity in the way of buildings, equipment, and labor, In the ice cream industry idle production capacity is especially great because the products are extremely perishable and can be stored only at high cost. Sufficient equipment must be maintained at all times to produce enough product when demand is at its maximum. With the seasonal change amounting to well over 200 per cent and with long and short-time changes in production of exceptional magnitude in addition, the resulting high maintenance cost causes prices of the products sold to be quite high. One alternative to high prices is to level out production and escape such

cost by cultivating a more uniform demand for the product. Substantial progress has been made in this direction. With improvements in quality and distribution methods accompanied by effective educational programs, especially those initiated by the International Association of Ice Cream Manufacturers and the National Dairy Council, consumers have tended to adopt ice cream as a staple food rather than a seasonal luxury.

ICE CREAM PRODUCTION, WHOLESALE AND RETAIL, BY MONTHS, 1947 [1]

Month	Thousand Gallons	Per Cent
January	37,769	6.0
February	36,828	5.9
March	44,230	7.0
April	52,902	8.4
May	62,520	9.9
June	67,719	10.8
July	76,061	12.1
August	77,683	12.3
September	61,644	9.8
October	48,071	7.6
November	32,441	5.2
December	31,222	5.0
Total	629,090	100.0

Frozen dairy products containing less butterfat or total milk solids than ice cream are made and sold under other names, such as ice milk, frozen custard, and a variety of brand names. They do not meet the minimum standards established in definitions for ice cream. Their manufacture and sale are prohibited in some states. In general, they contain a lower ratio of butterfat to milk solids-not-fat than ice cream. Total production of these products is minor compared with ice cream, especially from the standpoint of milk ingredients used. Their sale and distribution are similar to that of ice cream except that a higher proportion is distributed through direct retail sales outlets with the product being frozen at the point of sale from ready-made mix purchased from specialized distributors.

[1] Bureau of Agricultural Economics, U. S. Dept. Agr.

Chapter 9

ECONOMIC PHASES OF MILK BY-PRODUCTS

EQUALLY AS WASTEFUL AS THE OLD BEEHIVE COKE OVENS THAT PERMITTED valuable coal by-products to escape into the air, have been the dairy plants that allowed milk by-products to drain down the sewer. Yet thousands of gallons of skim milk, buttermilk, and whey are still thrown away or inefficiently used, especially during the season of flush production. The incidence of such waste has been greatly reduced during recent years but is far from being eliminated. The principal reason for this is that demand for dairy by-products has not been developed to the point where all these secondary dairy products can profitably be prepared for use. In other words, these secondary milk products, with known nutritional and industrial value, have not attained sufficient economic value to be used exhaustively. They consist of the bulky materials that remain after the most valuable portions of milk have been removed and concentrated in cream, butter, and cheese. The vast majority of them are available only at a distance from markets; therefore the way to increase their economic importance is to convert them into products that can be easily transported to factories and consumers. Since they are all perishable and contain a large amount of water, the first step in their preparation is to enhance their keeping qualities and reduce their weight by the removal of water. Desiccation, evaporation, fermentation, and separation are some of the processes resorted to in accomplishing this purpose, and a variety of milk by-products ultimately results.

DRIED PRODUCTS

Dried-milk products are the most important of these milk by-products. Although methods for drying milk have been known for centuries, techniques for preparing dried milk on a commercial scale were not perfected before 1898, and production was slow to develop until about 25 years ago. The table on page 95 traces the production of major dried-milk products from 1916 to 1947. Dried whole milk is not, of course, a by-product of milk but it is here included for comparative purposes. While production of dried whole milk is important and was expanded greatly during World War II, the dry-milk industry has been primarily concerned with the production of milk by-products, especially those made from skim milk.

Dry whole and dry skim milks were essential wartime food requirements. Meeting these requirements involved a program of accelerating the trend

[1] Harry C. Trelogan, Ph.D., Assistant to the Administrator, Agricultural Research Administration, U. S. Dept. of Agr., contributed this chapter.

toward greater deliveries of whole milk rather than farm-separated cream to creameries and expanding plants and facilities to manufacture the increased volume of skim milk which became available for processing. This phase of plant expansion was by far the greatest experienced by the dairy industry in recent times. Results of these changes are indicated by the following comparison: of the estimated 40 billion pounds of skim milk produced in this country in 1935, 7 billion pounds or about 18 per cent were used in the production of milk by-products; of the estimated 44 billion pounds produced in 1946, about 15 billion pounds or 34 per cent were manufactured into milk by-products.

Since the delivery of whole milk is desirable from the standpoint of efficient use of the nutrients of milk and since most farmers who shifted to delivery of whole milk probably will desire to continue this method of marketing their milk, large supplies of factory skim milk will continue to be available for manufacture. One of the most important problems of

PRODUCTION OF DRIED MILK PRODUCTS, 1916 TO 1945 [1]
(Thousand Pounds)

Year	Dried Whole Milk	Dried Skim Milk	Dried Buttermilk	Malted Milk
1916	2,123	16,463	342	11,654
1917	3,139	22,624	2,557	13,852
1918	4,164	25,432	4,341	15,623
1919	8,661	33,076	5,279	17,436
1920	10,334	41,893	5,586	19,725
1921	4,242	38,546	7,708	15,651
1922	5,599	41,217	9,007	13,659
1923	6,569	62,251	13,032	15,331
1924	7,887	69,219	18,058	15,899
1925	8,931	73,300	22,772	18,050
1926	10,768	91,718	31,378	20,673
1927	11,464	118,123	38,435	22,116
1928	9,605	147,990	45,502	21,128
1929	13,202	207,579	54,215	22,850
1930	15,440	260,675	64,601	22,691
1931	12,627	261,938	50,535	19,197
1932	11,983	270,194	48,712	13,215
1933	13,026	288,114	53,260	12,430
1934	15,869	294,935	53,636	13,569
1935	19,432	297,506	49,823	15,485
1936	18,180	349,550	50,781	18,495
1937	13,676	372,203	53,141	19,785
1938	21,496	449,291	63,910	15,394
1939	24,472	408,380	62,187	19,744
1940	29,409	481,805	67,931	20,021
1941	45,627	476,497	75,614	23,242
1942	62,167	626,562	69,687	34,679
1943	137,766	533,899	60,995	49,435
1944	177,754	599,319	56,683	40,549
1945	217,276	660,054	49,578	42,751
1946	188,406	667,169	38,627	45,029
1947	164,888	700,090	45,437	37,354

the dairy industry is to expand domestic outlets for skim-milk products, especially nonfat dry milk solids, so that prices of these products will be

[1] Bureau of Agricultural Economics, U. S. Dept. Agr.

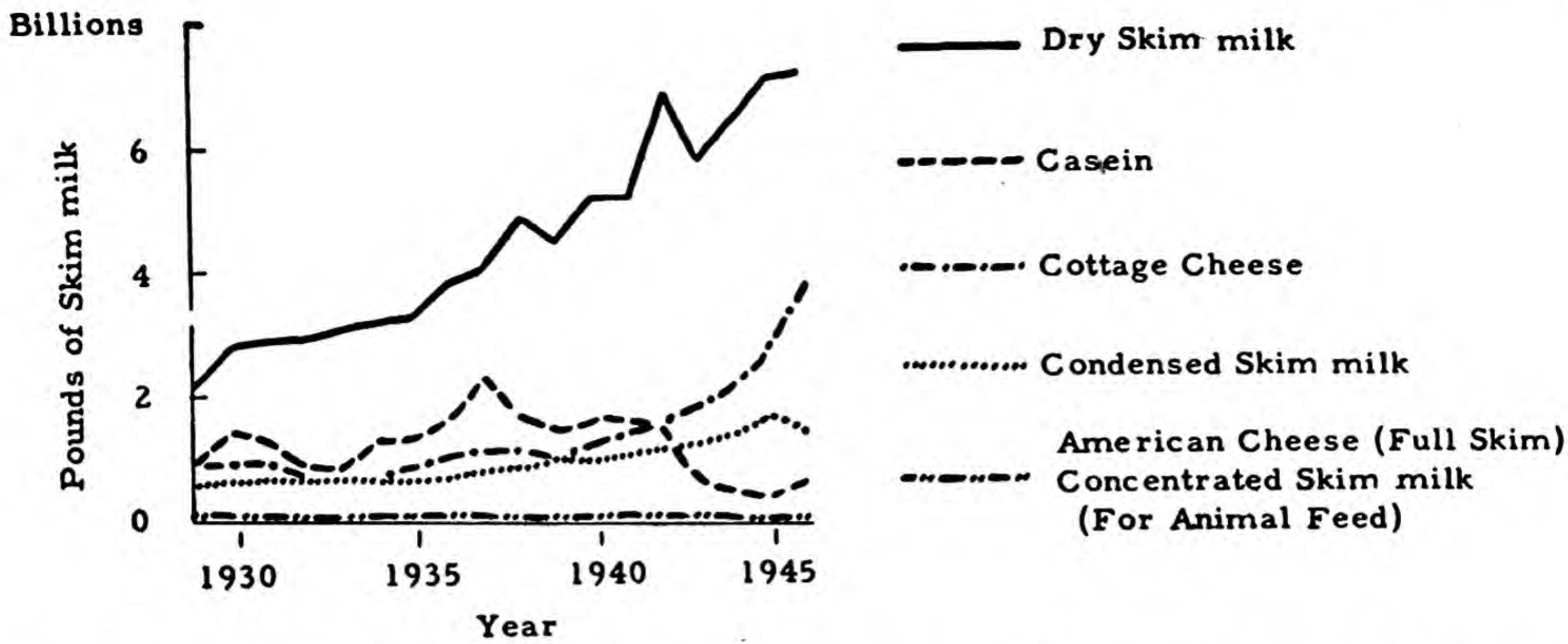

Fig. 20. Amount of skim milk utilized in the production of several milk by-products is given in the above graph.

maintained at remunerative levels, thereby encouraging producers to market whole milk and enabling processors to make exhaustive use of the milk solids available in commercial channels.

Over half the skim milk that is used in manufactured products is made into powdered milk products. Figure 20 indicates the relative importance of the various products in their utilization of skim milk. In addition to the manufactured skim milk by-products cited in Figure 20, about 1.5 billion pounds is used in skim-milk drinks, such as cultured buttermilk and chocolate drinks. Vast quantities of the remainder of the skim-milk supply is used for feeding livestock on farms where it is produced.

Two principal types of dried-milk products, viz., spray and drum-dried powders, are differentiated on the basis of the processes used in their production. Spray-dried milk is made by forcing a spray of milk into a chamber where it is dried in a current of hot air, settling to the bottom in the form of a white powder. Drum- or roller-dried milk is produced by spreading a thin film of milk over steam heated revolving drums on which the milk quickly dries and from which a continuous sheet of dried milk is scraped. This type which is sometimes made under a partial vacuum is pulverized before it is packed. In general, the drum drying process yields a less soluble product, but with improvements in the handling of the raw material and in processing the greater proportion of roller powder made from skim milk, meets requirements for human consumption, the remainder being utilized for animal feeds. Dried skim milk of inferior quality used for animal feed is now commonly denoted as dry skim milk as distinguished from nonfat dry milk solids which are suitable for human consumption. Spray-dried skim milk is used almost entirely for human consumption and usually demands a price premium over the drum dried product.

Plants used in the preparation of spray-dried nonfat milk solids are necessarily large, specialized, and expensive. They can be operated only in districts where the milk supply is plentiful and where a large part of it is separated for cream, because they must necessarily be operated near

capacity if unit costs of production are to be kept sufficiently low to make the enterprise profitable. Since the spray-dried product is usually consigned to human consumption, only high quality skim milk is used in its preparation. For these reasons, spray drying plants tend to be located near the outer limits of market milksheds where quantities of cream are separated from high quality milk.

Drum drying units are obtained in comparatively small sizes and are less expensive than spray dryers. They can be installed in less specialized plants and are operated in greatest number as adjuncts to butter producing creameries that have skim milk and buttermilk available for drying. Most of the drum-dried milks are produced in the Midwestern butter producing states.

Nonfat dry milk solids can be stored in cool, dry places without deteriorating unduly. Like other preserved dairy products, production is highly seasonal. This is to be expected since the skim milk supply fluctuates in direct proportion to butter and cream production. Returns obtained from the conversion of skim milk into dried products aid in augmenting and leveling out the income of farmers producing milk in butter and cream areas. Where milk is sold for market milk part of the year, this effect is especially beneficial for it serves to ease the shock of low surplus milk prices. Practically all nonfat dry-milk solids are packed in bulk, i.e., in barrels, drums, or bags of 100 to 200 pounds capacity. It is sold for the most part to food manufacturers who use it in large quantities. Its use in the household for cooking is increasing but has not kept pace with the rapid increase in demand for it by bakers, candy and ice cream makers, and prepared food manufacturers. Studies by home economists and household usage here and in other countries show that it has a definite place in the home pantry. It is probable that the future will find it stocked on retail grocery shelves where housewives can obtain it in containers of suitable size which protect the product until used. Considerable expansion in such utilization will be required to bring unit costs of packaging and distribution down to levels comparable with other dairy products.

Some dried-milk products made from skim milk are prepared in combination with other food products, such as cereals, sweetening agents, and flavoring materials. They are almost invariably branded products made and advertised for specific markets or purposes. Their aggregate production, however, is of minor importance.

CONDENSED SKIM MILK

Production of condensed-skim-milk products has been extremely variable in recent years. It consists of plain condensed skim milk and sweetened condensed skim milk, both of which are packed in bulk for similar types of uses. The sweetened product is less perishable and is subject to more sporadic production which has reached as high as 800 million pounds a year, but is generally less than plain condensed production which in late years has fluctuated between 400 and 500 million pounds.

These products are made for the most part in small factories that operate

condensing pans to diversify their milk outlets and in specialized plants developed to supply particular markets. Ice cream companies and candy manufacturers who desire a high percentage of milk solids in their products find them convenient sources of milk solids-not-fat. They are best suited for such purposes when large quantities can be used quickly so that they can be transported in carlots. The sweetened product is also useful, especially to ice cream plants highly dependent upon local milk supplies, for carrying skim milk over from times of surplus to periods of short production. A very small amount of sweetened condensed skim milk is packed as case goods and some concentrated skim milk is also made for animal feeding. All together these condensed-skim-milk products account for the utilization of some two to four billion pounds of skim milk annually.

Skim-milk cheeses. By far the most skim-milk cheese consists of the cottage variety. To some of it small amounts of cream are added and sold as creamed cottage cheese. Other variants, such as cottage cheese curd, pot cheese, bakers' cheese, farmers' cheese, and hand cheese, are prepared from skim milk with no subsequent addition of butterfat. Some farmers' cheese or cheese curd, however, is stored for utilization as a raw material in the preparation of cream, Neufchâtel, and similar varieties of cheese made during periods of short milk production. Several varieties of Italian and Greek cheeses are also closely related to cottage cheese and are essentially skim-milk products. For the most part these products have a high moisture content and poor keeping qualities and are prepared currently for prompt consumption. Total production of these cheeses evidently accounts for well over one and one-half billion pounds of skim-milk utilization. Since there is considerable duplication in their production figures because one item is used in the production of another, for example, cottage cheese curd used for the production of creamed cottage cheese, it is difficult to estimate a net production figure for them.

Another cheese made from skim milk is called full-skim American cheese. Ordinarily, the production of this product is very small. A part-skim American cheese is also made and sold in small quantities, rarely exceeding more than a few million pounds annually.

Casein. Historically, casein has ranked as an important outlet for skim milk accounting for well over one billion pounds of skim-milk utilization annually, but in recent years the diversion of skim milk to food products has caused domestic casein production to fall off sharply. Heavy importations of casein have helped to offset the decline in domestic supplies, but this product stands as a potentially valuable outlet for skim milk when it becomes more readily available. Casein has long been recognized as a valuable animal protein that has many uses. The protein can be precipitated out of skim milk easily with the addition of acid and in this way many creameries can obtain it in crude form and ship it, either as wet curd or dried casein, to industrial markets where it is frequently ground and bleached. Some large companies also produce casein under carefully controlled conditions, using rennet as well as acid precipitation to obtain

a rather chemically pure product that is adaptable to specialized food uses, as well as industrial uses. Among the more important uses for which casein is particularly well suited are paints, adhesives, paper coatings, plastics, and textiles.

Other skim-milk products. A variety of other products are made from skim milk. The most important of these, however, are cultured buttermilk and flavored drinks, especially chocolate drinks, which together account for the utilization of nearly one and one-half billion pounds of skim milk. Skim milk curd, which is very closely related to either cheese curd or casein, finds a wide variety of similar uses for cosmetics, plastics, and the like.

Buttermilk. The composition of buttermilk, which is the by-product of creamery butter, as distinguished from cultured buttermilk, is quite similar to that of skim milk but only a relatively small amount of it is used for direct human consumption. Most of this is prepared as dried buttermilk or incorporated with skim milk in the preparation of dry-milk products. Dried buttermilk production which usually exceeds 50 million pounds annually has declined along with the reduction in creamery butter output. The majority of dried buttermilk is prepared by the drum drying process for animal feeds, but some buttermilk obtained from the churning of sweet cream is spray dried for use in the preparation of human foods, such as special baby foods.

Closely rivaling dried buttermilk in importance is condensed, evaporated, or semisolid buttermilk. All of these products utilize annually about one billion pounds of buttermilk, or less than half the total supply. A large share of the remainder is returned to farms for animal feeding where its value approximates that of skim milk.

Whey. Whey is a by-product of both cheese and casein production. Whey that remains after the removal of casein from skim milk in large, specialized by-product plants is used as a raw material for the production of valuable products such as albumen, alpha lactose, beta lactose, lactic acid, and various lactates of metal. Markets for these products are generally of a specialized nature and quite limited in scope. Cheese whey is usually of lower quality than casein whey but it is a potential source of most of these products which might be tapped any time the supply of casein whey proves inadequate to meet the demand for such products.

Whey that is obtained incidental to cheese production usually contains enough butterfat to justify separating it to recover the fat. Some of it is then used for animal feeding, some for drying in the production of whey powder, and some for obtaining milk sugar or lactose and albumen, and a small quantity is concentrated into whey cheese or Primost, as it is known in the Scandinavian countries.

Because it is an excellent source of riboflavin, the concentrating and drying of cheese whey for animal feed has expanded in recent years. The 140 million pounds annual dried whey production represents the most important outlet for this by-product. Considerable quantities of whey are

still discarded by small, isolated cheese factories that do not have enough of it to compensate for processing or are too far from processing plants to compensate for transporting it to them.

Collection of whey from numerous cheese factories for processing at centralized plants was stimulated during the war by the urgent need for milk sugar. The great expansion in demand for milk sugar occurred when it proved to be a valuable ingredient in the culture media for producing penicillium mold from which the "wonder" drug pencillin is produced. In response to this demand, production of milk sugar was increased from an average of about six million pounds per year to more than 20 million pounds. Much of the milk sugar is marketed as crude sugar for direct utilization in penicillin production or other uses. The majority of the crude milk sugar, however, is refined for utilization in pharmaceuticals, baby foods, and a wide variety of minor uses, as well as for penicillin. The whey residue remaining after milk sugar is extracted is largely utilized in the production of animal feed products.

Chemists and food technologists have found literally hundreds of uses for the basic materials found in milk by-products and it is predicted that milk will assume a still more important role as a source of industrial raw materials in the future.

Chapter 10

ORIGIN, DEVELOPMENT, AND CLASSIFICATION OF DAIRY CATTLE

HOW INFORMATION IS OBTAINED

WHILE THE ORIGIN AND EARLY DEVELOPMENT OF CATTLE IS NATURALLY obscure, much light has been thrown upon the subject by students of history, paleontology, and zoology. By discovering here and there bits of description or crude sketches of cattle in the earliest records of man and later from more complete descriptions of different breeds and species of cattle, the historian has contributed materially to our knowledge of the probable development of our domesticated cattle. The paleontologist, by careful search for remains of prehistoric and later forms of cattle and by careful study of the parts found, has been able to piece together a fascinating and informative story of the earlier forms and the changes down to the present. The zoologist has contributed to the subject through studies of the structure of the different parts of the anatomy of the species. By observing the differences and similarities of the species and breeds the zoologist can determine relationships which suggest the manner of development.

When the results of the work are brought together, a fairly coherent and logical story of the origin and development of domestic cattle is presented.

The Family and Genus

All domesticated cattle belong to the family *Bovidæ*, whose members ruminate, have hoofs with an even number of toes, and differ from some other ruminants by possessing permanent horns with a bony core. Members of the family have been found in fossils going back to the Miocene age. Domesticated cattle are descendants of wild species belonging to the genus *Bos*. This genus has five subgenera or groups. Although cattle are descendants of only the first or taurine group, these groups are listed and briefly described, in order to show the close relationship of the other groups to cattle.

1. *Taurine group.* All domesticated cattle belong to this group. Its members roamed over Europe, Asia, and Northern Africa from the Miocene period until rather recently. Only those that have escaped from domestication are found in the wild state today. They differ from other groups of the genus by having cylindrical horns which are set wide apart on a ridge on top of the skull, a flat forehead, with the eyes far below the horn, and long nasal bones. The back is straight and the hair short. The spinal processes of the dorsal

vertebrae slope toward the posterior and are of moderate height. Subdivisions of this group will be discussed later.

2. *Bibovine group.* These are humped forms and are natives of southern India. The forehead is shorter with less width at the base of the horns than that of the taurine group. The banting and gam, which measure nearly six feet in height, belong to this family, as does the gayal.
3. *Leptobovine group.* This group is extinct. Fossil remains have been found in France, Italy, and India. The fossil bones indicate that members of this group were rather small. Their horns were cylindrical and curved, but were attached far below the vertex of the skull.
4. *Bisontine group.* The American bison, the European bison, and the Yak are members of this group. The Yak still ranges over large parts of Asia in the wild state and is also extensively domesticated. The American bison, often but erroneously called buffalo, has not been domesticated except for crossing with cattle for the hybrid "cattalo."
5. *Budaline group.* This group is represented by the true buffalo of Asia and southeastern Europe, where it is used for milk production, for beef, and as a draft animal.

The Taurine Group

The taurine group is divided into two species: (1) *Bosaurus typicus*, which includes all domesticated types without humps, and (2) *Bosaurus indicus*, those having humps. The latter is confined to Asia and Africa in the form of the zebu, except for the few that have been imported for crossing with cattle, particularly in southeastern United States. The zebu has a hump over the withers, large drooping ears, and a grunting cry which distinguishes it from *Bos typicus*. No wild forms of the zebu have ever been found; its complete domestication is reported to have taken place as early as 2000 B.C. It crosses readily with *Bos typicus*, and some students believe that zebu crosses played a part in the development of some of the European breeds of cattle. *Bos taurus typicus* includes all the modern breeds of cattle in Europe and America. According to Morse [1] there are four wild forms of this species from which the modern breeds have sprung. They are *Bos primigenius*, *Bos longifrons*, *Bos frontosus*, and *Bos brachycephalus*. This classification is based largely upon skull characteristics and is not agreed to by all students of the problem.

Bos primigenius was a large animal 6 or 7 feet in height at the withers, which roamed over all of Europe, Western Asia, and Northern Africa during the Pleistocene and recent geologic periods. The horns were long and strong, and made a semicircular curve forward; the forehead and face were long and narrow. The whole cranium was flat, presenting a straight line from a lateral view. There is evidence that wild specimens of *primigenius* have lived in historic times. Caesar, Tacitus, and Pliny referred to them as urus. (Fig. 21.) Tacitus and Pliny described drinking horns that held as much as two ur (about 12 quarts). Some authorities believe that the wild forms were not exterminated until the seventeenth century.

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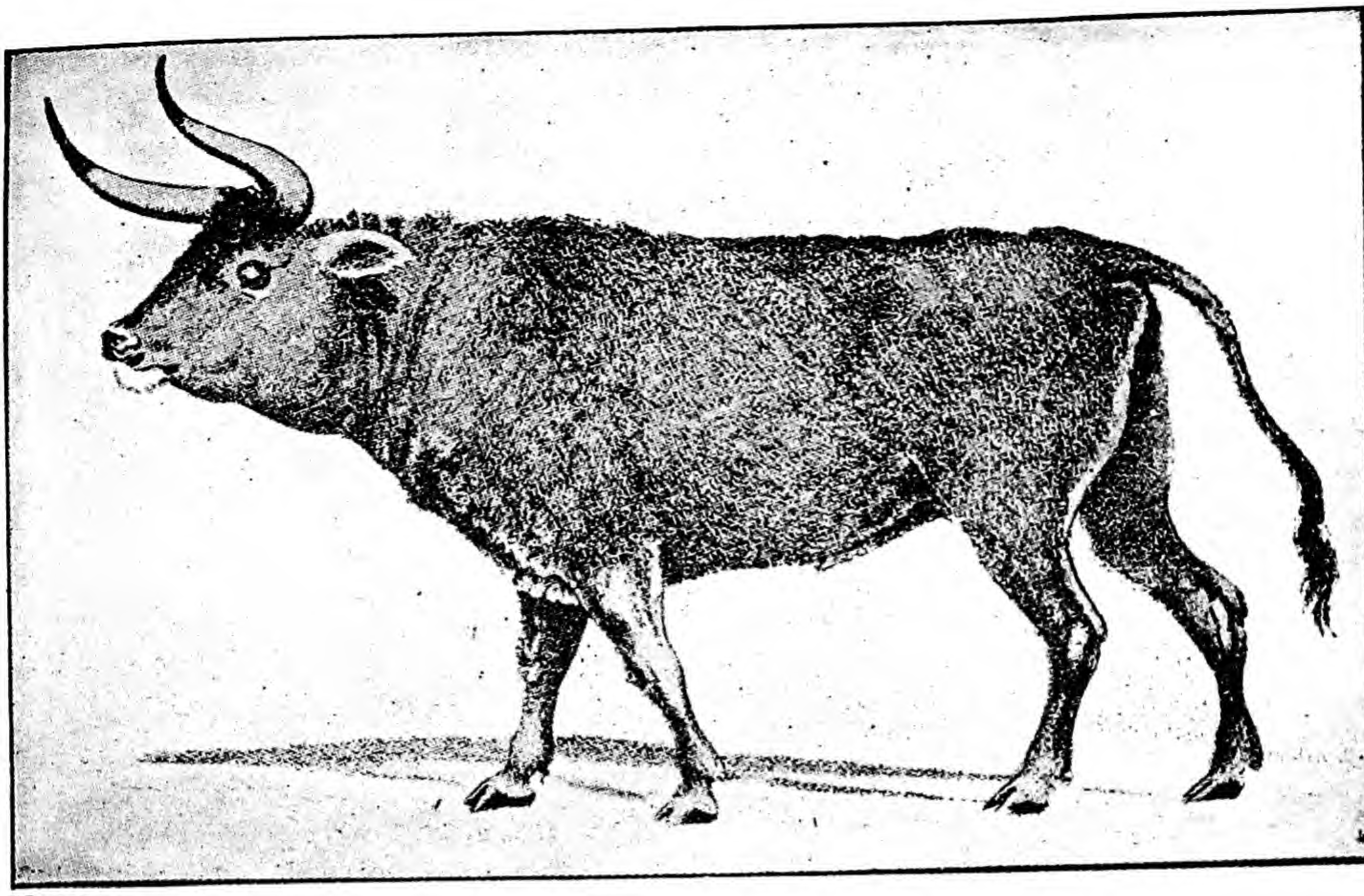
[1] MORSE. *The Ancestry of Domesticated Cattle.*



Morse

Fig. 21. The Augsburg painting of the Urus.

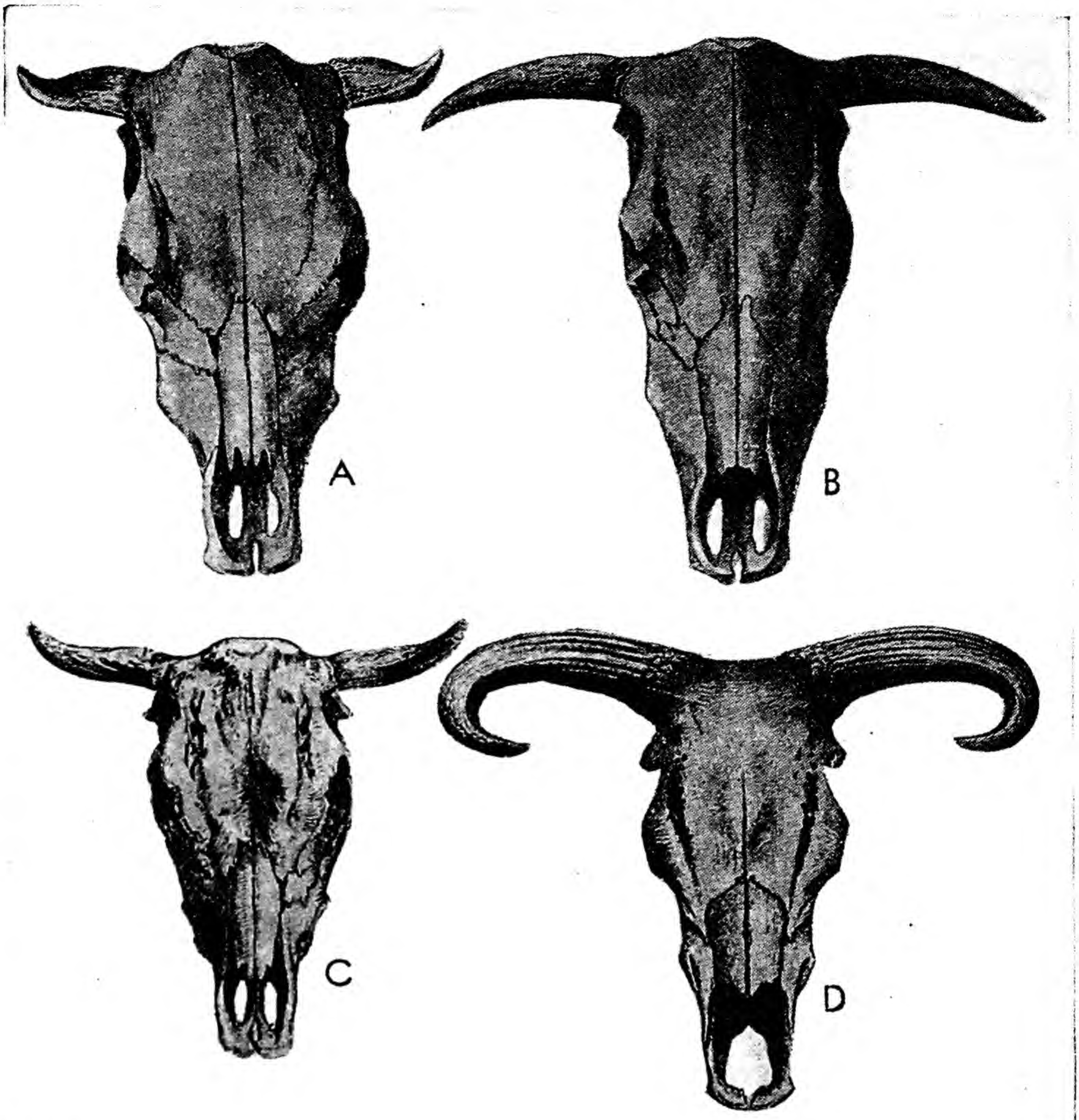
The wild cattle of Chillingham Park, England, are said to closely resemble the wild *Bos primigenius*.

Bos longifrons were much smaller than *Bos primigenius*. (Fig. 22.) The horns of the former were shorter, as was the face, but the forehead was longer and broader than that of *Bos primigenius*, with a ridge in the center of the poll. *Bos longifrons* was of solid color, a black-brown to gray. Its forehead, too, was deeply dished. The time of origin of *Bos longifrons* is speculative, some claiming its existence in the Pleistocene age, while others claim that it is of a more recent origin. *Bos longifrons* was found all over Europe during the Stone Age and in England during the Roman occupation. It is generally credited as being the ancestor of the Welsh and Highland breeds.

Bos frontosus is found in fossil form in Sweden. Its head, large in comparison to the rest of the body, had an irregular contour with wide forehead. The horns were relatively straight and came out from the top of the skull. *Bos frontosus* is believed by some to be the ancestor of the mountain cattle of Scandinavia; by others it is said to be the domesticated form of *Bos primigenius*. The Simmenthal breed of Switzerland and some spotted breeds of southern Germany are of the *frontosus* type, lending support to the contention of some people that its origin was in Germany.

Bos brachycephalus, a short-headed race like *Bos frontosus*, does not have the support of all authorities as being a distinct type equal with *primigenius* and *longifrons*. The skeletons found in the moors of Laibak had heads with foreheads broader than long, and horns attached to a short pedestal.

Whether or not *Bos brachycephalus* and *Bos frontosus* are proved types



Morse

Fig. 22. Skulls of four types of progenitors of domesticated cattle: A, *Bos longifrons;* B, *Bos frontosus;* C, *Bos brachycephalus;* D, *Bos primigenius.*

separate and distinct from *Bos primigenius* and *Bos longifrons*, the latter two are unquestionably the most important in the development of the modern breeds.

HISTORY OF CATTLE IN EUROPE

Since all the American and European breeds of cattle originated in Europe, a brief history of the development of cattle in Europe will be the history of the development of the modern breeds. Exactly when cattle were first domesticated is not known, but that cattle were domesticated at a very early stage of human civilization is certain. Long before man was able to make records, cattle were used by him as beasts of burden

and for food. This has been proved by the discovery of the skeletons of cattle in ancient cave dwellings in Switzerland, together with the cave dweller's remains and the crude stone implements which he used.

It is probable that as man changed from savagery to a barbarian stage of civilization, he began to domesticate cattle. With the advent of the Bronze Age, man in all probability began the development and breeding of cattle. The earliest of written records refer frequently to cattle; they are mentioned frequently in the Old Testament of the Bible. The oldest of drawings upon the walls of caves in Switzerland depict cattle as beasts of burden; and from the emphasis given to the udders, it may be assumed that milk production was stressed. The great philosophers of 2,000 years ago, especially Pliny, wrote of cattle breeding as an art. Alexander the Great is said to have imported into Greece more than 2,000 cattle from India. Caesar wrote of the milk and cheese produced in what is now Holland. The Romans brought cattle with them in their invasion of England, and the Celts took cattle with them wherever they went. These are just a few of the many known facts about the early history of cattle in Europe.

Origins of Breeds

How so many breeds have come into existence may readily be understood if one takes into account the fact that cattle were scattered throughout early Europe and that there was little communication between the various peoples, who were banded together in groups for protection against conquest. It is to be expected that each group would select their cattle for certain characters, that these characters would differ from those for which other groups selected their cattle, and that each group would continue to breed for such characters. Sooner or later, then, all the cattle in one locality would become rather pure for such character or characters, and would become a *breed*. In addition, climatic and food conditions in the different localities had their effect upon the selection of types. The cold of the North necessitated selection for resistance to cold. Scarcity of grazing forced the selection of specimens that were good grazers, while a different, less aggressive type suited the conditions in localities where grasses were luxuriant.

In America there are about 17 breeds of cattle; in Britain there are more than 60 breeds, as listed by McConnell; and in Germany there are about 50 or 60 breeds. The improvement of breeds is discussed in Chapter 24, "Systems of Breeding."

Classification of Cattle

Cattle may be classified according to breed, origin, use, and degree of purity. According to Werner the breeds can be grouped according to the type from which they descended, as follows:

Bos primigenius

Holstein-Friesian
Dutch Belted
Shorthorn
Normandy
Polled Durham
Red Polled
West Highland
Galloway
Aberdeen Angus
Ayrshire (crossed with *longifrons*)

Bos frontosus

Simmenthal
Breeds of Sweden

Bos longifrons

Brown Swiss
Jersey
Guernsey (crossed with *primigenius*

Bos brachycephalus

Kerry
Brittany
French Canadian
Hereford
Sussex
Devon

Morse criticizes this classification, stating that the Hereford has about the same origin as the Normandy breed, and that the Ayrshire, West Highland, and Galloway have more *longifrons* than *primigenius*. He also believes that the Kerry and Brittany are more *longifrons* than *brachycephalus*.

Classification according to use. Cattle may be divided into groups according to the use for which they have been specialized. These groups are dairy, beef, dual-purpose, and beast of burden. As oxen belong to an era of the past, no breed in America is bred for this purpose. The American breeds are divided as follows:

Dairy Breeds	Dual-purpose	Beef Breeds
Holstein-Friesian	Red Polled	Hereford
Jersey	Devon	Shorthorn
Guernsey	Milking Shorthorn	Polled Shorthorn
Ayrshire		Galloway
Brown Swiss		Aberdeen Angus
Dutch Belted		
French-Canadian		
Kerry		

Classification according to degree of purity. Cattle may be divided into four classes according to the degree of purity. The four classes are purebreds, grades, crossbreds, and scrubs.

Purebreds. Purebreds are cattle that trace back through all lines to the foundation cattle of the breed. While they may not necessarily be registered, most purebred cattle are also recorded on the books of their Breed Association office. All "registered" cattle are purebreds. Another term

used for purebred is full blood. Thoroughbred is sometimes improperly applied to purebreds.

Grades. There is no universally accepted definition for grades. Some maintain that in order to qualify for the classification of grade, one parent, usually the sire, must be purebred. In common practice, however, any animal not purebred that possesses the major characteristics of a breed is classed as a grade of that breed. When successive purebred sires are used, grades continually approach purebreds in purity, but such animals cannot be registered in America.

Crossbreds. Crossbreds is a term applied to the cross between two breeds; the parents may be purebreds or grades. Crossbreeding is often resorted to when one wants to change from beef production to dairying or vice versa. Some dairymen also resort to crossbreeding when they desire to increase the fat percentage in the milk or the amount of milk to satisfy special market demands.

Scrubs. Animals that do not possess the chief characteristics of any breed or that cannot be classified in any of the above classes are usually referred to as scrubs. The term *scrub* is also applied to animals of undesirable characteristics even though they may be purebred. Other terms used in designating nondescript animals are *mongrel* and *unimproved.*

Chapter II

THE HOLSTEIN-FRIESIAN

HOLSTEIN-FRIESIAN IS THE OFFICIAL NAME OF THIS BREED IN AMERICA although it is commonly referred to as "Holstein." In Europe and in most other countries, the breed is known as Friesian.

Characteristics. The characteristics of the breed are discussed under the following headings:

Size. The Holstein is one of the largest of the breeds of cattle. The standard is 1,250 pounds for cows and 1,800 pounds for bulls. Several cows have reached a ton or more in weight, the largest recorded being Mantup Pietje Bess Ormsby, who weighed 2,400 pounds.[1] The first prize 3 year old bull at the 1934 Dairy Cattle Congress weighed 2,800 pounds. Plumb [2] reports a purebred Holstein steer weighing 4,365 pounds.

Color. A Holstein to be eligible for registration must be black and white, varying from nearly all white to nearly all black. The following colors bar registry:

1. Solid black
2. Solid white
3. Black switch
4. Solid black with white on belly only
5. Black on legs, beginning at the feet and extending to the knees and hocks
6. Black on legs beginning at the feet and extending to the knees, with white interspersed
7. Gray, or mixed black and white generally prevailing
8. Patches of colors other than black and white; red, brown, dun, etc.
9. Red and white

The relative amounts of either black or white vary from white with only a small black spot to an almost total black, except for the switch, which must always be white. Red and white is present in the Holstein as a recessive color and crops out occasionally. In Holland, red and white Holsteins are common; in America, while they do occur, they cannot be registered.

Type. The Holsteins are ruggedly built, with large middles and udders. The head is long and comparatively narrow, with a straight profile. In dairy conformation they vary from extreme clean-cutness to a

[1] Holstein-Friesian World. Lacona, N. Y. July 15, 1933.
[2] PLUMB. *Types and Breeds of Farm Animals.* Ginn and Co., Chicago. 1914.

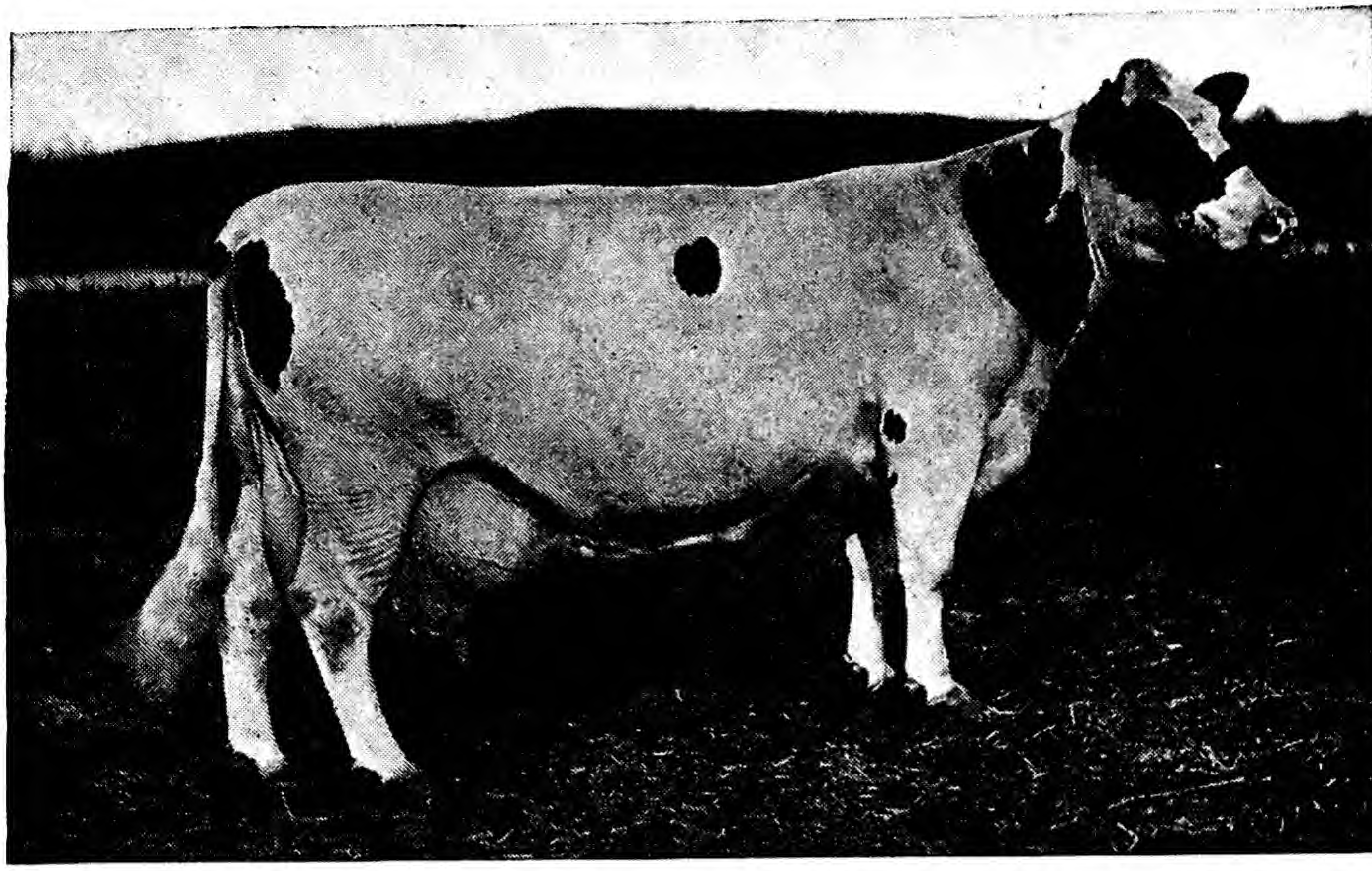


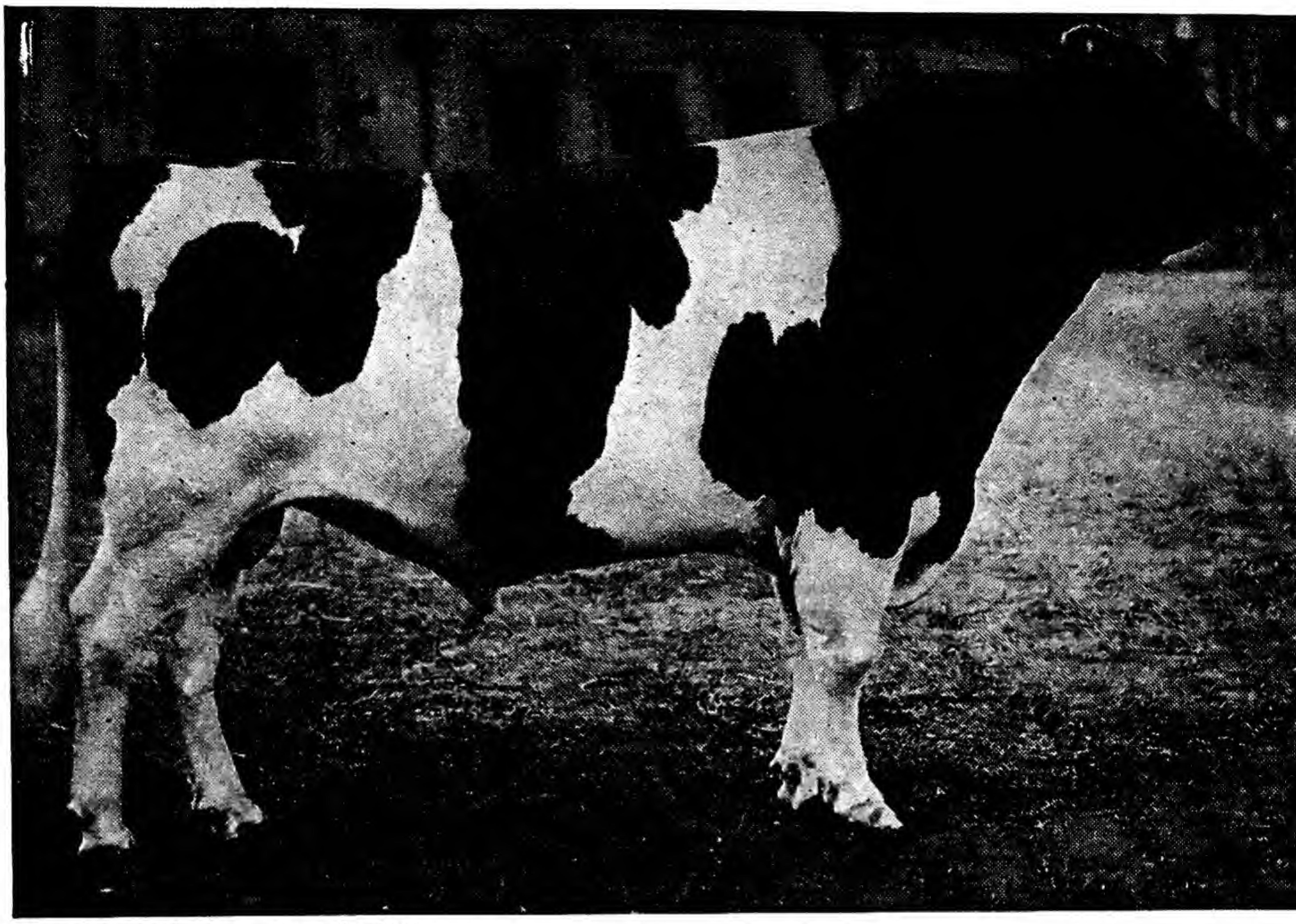
Fig. 23. Carnation Ormsby Butter King 1165152. This cow combines high production with good type. She holds the world's record for Holsteins for both milk and butterfat with 38,606.6 pounds of milk and 1,402.0 pounds of butterfat.

"rounding" type—rounding over the withers, slightly outcurving thighs, and moderate thickness of flesh throughout. The most desirable type is slightly rounding over the withers and straight in the thighs. The Holstein is frequently criticized for being low at the pinbones and for lack of symmetry of the udder. (Figs. 23 and 24.)

Disposition. The Holstein cow is rather phlegmatic and docile. This characteristic is no doubt due to the environment in which she was developed, where excitable and nervous individuals were not selected for breeding stock. The bulls, however, are frequently vicious. As a grazer the Holstein ranks fair on moderate to poor pastures and excellent on good pastures. Her large size increases her nutrient requirements and handicaps her on poor pastures, since she has to cover much more ground than a smaller cow to secure the needed nutrients.

Reproduction and longevity. Holsteins are not noted for longevity although they average up well with other breeds. Individuals attaining unusual age are not so frequent as in some other breeds. Holsteins are good reproducers. The calves are strong and vigorous, weighing, on an average, about 90 pounds at birth. The birth weight of the calves averages about 7.8 per cent of the body weight of the dam.

Maturity. The Holsteins are late maturing. Heifers are usually not bred until 19 to 21 months of age, producing the first calf at from 28 to 30 months of age. The Holstein attains maximum growth and development at about seven years of age. Only the Brown Swiss among the dairy breeds is later in maturing than the Holstein.



Holstein-Friesian Association

Fig. 24. Denver Ormsby Denver Prince 631492 is an excellent Holstein bull. He was All American aged bull in 1936 and All American three year old in 1934. Four of his daughters have official records averaging 514 pounds of butterfat and 14,520 pounds of milk.

Meat and veal. The Holstein ranks highest among the dairy breeds for meat production. It has the largest carcass of the dairy breeds, is the thickest fleshed, and has the lightest color of body fat. In some tests Holstein steers have shown up favorably with beef breeds in rapidity of gains and in the quality of beef produced. For veal production the Holstein ranks with the best because of the size of the calf at birth and the light color of the body fat.

Character of milk. Averaging 3.5 per cent fat, Holstein milk has the lowest fat content of any of the diary breeds. Some produce milk with less than 2 per cent fat. The low fat content of the milk of some Holsteins has given rise to a serious problem in furnishing market milk. Some milk markets demand a 4 per cent fat milk, and milk producers with Holsteins have found it necessary to introduce cows of the higher testing breeds in order to meet the market requirements. By careful selection of bulls many breeders of Holstein cattle have succeeded in raising the fat percentage of the herd up to as high as 4 per cent.

Holstein milk and butter rank low in color, although some individuals produce milk that is fairly high in color. The Holstein apparently converts carotene, which is responsible for the yellow color of the fat and milk, into colorless vitamin A. With the exception of that of the Ayrshire, the

fat globule of Holstein milk is the smallest of all breeds. Because of the small fat globules and low fat content of Holstein milk, claims have been made for its superiority for infant feeding. Such claims, however, are not too well supported by scientific facts.

The small fat globule and the low fat content of Holstein milk adapt it well for cheese making. The small fat particles slow up the rising of the fat, and thus better incorporation of fat into the setting curd is permitted. The fat constitutes 28 per cent of the total solids; this is the best proportion of fat to solids-not-fat for both cheese making and evaporated milk.

The home and origin of the Holstein. The Holstein breed was originally developed in two provinces of Holland, North Holland and West Friesland. The early development is obscure, but it is agreed that these cattle are descendants of the wild species *Bos primigenius*. It is also agreed that they have been bred in Holland for 2,000 years or more. No doubt the conditions in Holland have had a marked influence on the characteristics of the Holsteins of today.

Since the fertile soil and abundant rainfall of the region produce luxuriant pastures, the Holstein-Friesians of Holland have had to live almost entirely upon grass during the summer months. Because of the luxuriance of the pastures, poor grazers were at no particular disadvantage to good grazers and were, therefore, not eliminated in the development of the breed.

Because winters were cold, it was necessary that the cows be stabled. The stables and homes were frequently under the same roof, necessitating docile animals. The custom of milking the cows out on the pasture also contributed toward the selection of docile animals. This development is reflected in the general character of the members of the breed, as has already been discussed.

The low fat content of Holstein milk can also be explained by environmental factors during the early development of the breed. The chief dairy product of Holland, probably even before the beginning of the Holstein breed, has been cheese, and large quantities of milk are of more importance than high fat content for cheese making. The selection for one of these characters has a tendency to reduce the other. Since the Holsteins were selected for large quantities of milk production without regard to the fat content, the characteristics of the breed of today resulted.

Today the Holsteins (or Friesians, as they are called in Holland) are very highly developed in Holland and are described as somewhat more thickly fleshed than the American Holstein. Since the red and white colors have not been objected to in that country, they are quite common.

The Holstein-Friesian has given rise to several other breeds. The Lakenfelders or Dutch Belted, the Gronigen of Holland, and the East Friesian and the Oldenberg of Germany, as well as breeds in Russia and Sweden, have all originated from the Holstein-Friesian stock.

Importation. Records of 1621 and 1625 reveal that the first Dutch settlers in America brought Holland cattle with them. In 1795 six cows and two bulls were sent to New York, but no descendants of these have

been traced. The first importation to be kept pure was that made in 1852, when Wintrop Chennery of Massachusetts bought one cow from a Dutch boat. In 1859 Mr. Chennery imported four more cows, and from these he developed a herd that had spread to 12 states by 1871. Up to the end of 1871 a total of 30 head had been imported. Following 1878 the importation of Holsteins from Holland became a big business, reaching a peak in 1885, when 2,538 head were imported in one year. After this, there was a rapid drop in importations. In 1905, the last time that Holsteins were brought from Holland to this country, only 30 head were imported. A total of 7,750 Holsteins have been imported into the United States.

Distribution of Holstein-Friesians. The Holstein-Friesians are found in all major countries of the world. In the United States, Canada, Holland, and Japan, Holsteins outrank any other breed from the standpoint of numbers. In Japan 80 per cent of all cattle are Holsteins; and in Canada there are more Holsteins than all other breeds combined. In England the Holstein ranks second to the Dairy Shorthorn in numbers. In Germany a large proportion of the cattle are Holsteins, and several of the German breeds have been developed from original Holstein-Friesian stock. Large numbers of Holsteins are found in Africa, South America, Mexico, Australia, and New Zealand. To the latter four geographic divisions and to the Orient Holsteins have been exported from the United States.

In the United States Holsteins are found in every state. They are the most numerous in the Eastern and North Central states, and in Washington and California in the West. The Holstein is less popular in the South than the smaller breeds. This is largely due to the fact that Holsteins cannot endure heat as well as the smaller breeds can. The five states having the largest number of Holsteins are New York, Wisconsin, Pennsylvania, Ohio, and Michigan.

Families. The Holstein-Friesian breed in America is credited with over 30 families.[1] In the strictest sense, there are no distinct families in the Holstein breed. Rather than saying a Holstein belongs to a certain family, it is more proper to say that it traces back to a certain foundation. De Kol 2nd is the foundation cow of the so-called De Kol family, and appears in the pedigrees of 74 out of the first 75 cows to produce 1,000 pounds of butterfat. Johanna, the foundation cow of the family by that name, appears in 54, Inka, in 41, and Aaggie in 72 of the pedigrees of the first 75 cows to produce 1,000 pounds of fat. Other great foundation animals similarly appear in the pedigrees of most of these highest producing cows of the breed; this shows that the descendants of great foundation animals have been so interbred as to largely eliminate family lines.

The more noted foundation cows of the breed are De Kol 2nd, Pietertje 2nd, Chlothilde, Aaggie, Johanna, Colantha, Belle Korndyke, Segis, Inka, Lillian Walker, Aaggie Cornucopia Pauline, Pielly, Helena Burke, Aaltje Posch, Springbrook Bess Burke, Pietertje Maid Ormsby, Mooie,

[1] PRESCOTT, PRICE, WING, AND PRESCOTT. HOLSTEIN-FRIESIAN HISTORY. Holstein-Friesian World, Lacona, N. Y. 1930.

Mercedes, and Tritomia. Descendants may or may not carry the names of the foundation animal to which they trace.

Herd books. The records of the Holstein breed are kept by the Holstein-Friesian Association of America, located at Brattleboro, Vermont. This association was organized in 1885 through the union of two associations existing prior to that time. These were the Holstein Breeders' Association of America and the Dutch Friesian Herd Book Association of America. The first herd book was established by the former in 1871, and by the latter in 1877. Animals registered in the former bear the suffix H.H.B. and the latter D.F.

In 1892 some Western breeders formed the Western Holstein Friesian Association, which published one herd book and then united with the Holstein-Friesian Association of America in 1898.

Up to July 1948, 2,863,969 females and 1,015,333 males had been registered by the Association. The number of registrations for one year reached a high of 169,338 in 1946. In 1947, 152,739 registrations were made. The all-time record for transfers issued was also set in 1946 with 116,285; 1947 ranks second, with a total of 100,873 transfers being issued. During the depression years, registrations and transfers fell off markedly. In 1932 the total registrations were 68,315.

Advanced Registry. One of the important milestones in the Holstein-Friesian history was the establishment of the Advanced Registry. This had its beginning in the Dutch-Friesian Herd Book, started by Solomon Hoxie, who later became the first Superintendent of Advanced Registry for the Holstein-Friesian Association of America. In order to obtain recognition in the Dutch-Friesian Herd Book, a mature female must have produced at least 10,000 pounds of milk in one year; heifers not in milk have to meet certain prescribed development of escutcheons to be eligible; and two to two and one-half year olds must have produced 6,000 pounds of milk.

The first Advanced Registry of the Holstein-Friesian Association of America, established in 1885, required that mature cows produce not less than 15 pounds of butter in seven days, or not less than 10,700 pounds of milk in 365 days, or not less than 589 pounds of milk in ten days. Requirements for younger animals were proportionately lower, calling for 6,500 pounds of milk in one year from a two year old. These records were made by the owner. In addition, the animals had to score 75 per cent in the scale of points, and had to be inspected for "type."

In 1893 the requirements for type were dropped. In 1894 the Babcock test was adopted, and prizes were offered for the best seven day records made under the supervision of the superintendent of the Advanced Registry or representatives of experimental stations. This was the beginning of official testing. Later these tests were extended to seven days, eight months after calving, 30 days, 90 days, and 100 days. In 1908 the semiofficial test for 365 days was adopted, official inspection being made on two days each month. In 1917 the semiofficial test for 305 days was adopted. Since then

many changes have been made in the requirements and classification of tests.

Official tests. The records supervised fall into two classes: Official Testing, and Herd Improvement Test. Both of these are administered by the superintendant of Advanced Registry, located at Brattleboro, Vermont.

Official Testing. Records of 7, 30, 90, and 100 days in length must have supervision for the entire test. These are known as A.R.O. (Advanced Registry Official), as distinguished from the tests for the longer periods, which are known as A.R.S.O. (Advanced Registry Semiofficial). A few long-time tests have had constant supervision and are designated A.R.O. All inspections are done by representatives of the agricultural colleges.

To qualify for a 305 day test, a cow must make 85 per cent of the requirements of the 365 day test and must produce a living calf within 14 months of the previous calving. A 305 day and a 365 day record may be made in the same lactation. These records are again divided into three classes designated by 4X, 3X, and 2X.

"4X" designates a record where the cow was milked four times a day for more than 45 days.

"3X" designates a record where the cow was milked not more than three times daily except for the first 45 days.

"2X" designates a record where the cow was milked not more than two times daily except for the first 45 days.

To be eligible to enter in the Advanced Registry, the cow must meet the requirements set forth in the following table for age and type of record:

REQUIREMENTS IN POUNDS FAT

Age	7 Day Record	305 Day Record	365 Day Record
	Pounds	*Pounds*	*Pounds*
2 years	10	270.3	318
3 years	12	316.2	372
4 years	14	282.1	426
5 years or over	16	360.0	480
For each 1 day	.0055		.148

Bulls are eligible for Advanced Registry when four daughters have qualified for the Advanced Registry.

It is of significance to note that for the past ten years there has been a decided decrease in the percentage of 3X and 4X records. In 1938, 18.4 per cent were 4X, 65.4 per cent were 3X, and 16.2 per cent were 2X. In 1947 the percentages for 4X, 3X, and 2X were 2.5, 47.0, and 49.5 respectively.

The first table on page 115 summarizes all yearly records by age groups.

A total of 4,129 cows have exceeded 800 pounds of butterfat in 365 days; 416 have exceeded 1,000 pounds; 88 have exceeded 1,100 pounds; and 21 have exceeded 1,200 pounds up to July 1948.

	No. Cows	Days	Milk	Per Cent	Fat
Aged Cows	19,188	350	18,794	3.4	648.3
Senior Fours	4,125	351	17,631	3.5	612.0
Junior Fours	4,362	348	17,143	3.5	593.3
Senior Threes	4,961	349	16,311	3.5	566.0
Junior Threes	5,395	348	15,327	3.5	532.2
Senior Twos	7,272	354	14,648	3.5	506.5
Junior Twos	12,694	355	13,994	3.5	485.9
Average for	57,997	351	16,482	3.5	570.4

Highest Record in Each Type of Test on January 1, 1936

Name and Number	Age Y.M.D. (Y—Years M—Months D—Days)	Milk	Per Cent	Fat
7 days				
Pansje Prilly Abbekerk 766722	5–0–3	567.1	7.1	40.4
30 days				
Daisy Aaggie Ormsby 3d 571569	7–5–9	3,218.7	4.4	143.0
305 days				
Aaltje Salo Hengerveld Segis 823991	9–3–20	28,056.8	3.5	995.9
365 days				
Carnation Ormsby Butter King 1165152	8–5–27	38,606.6	3.6	1,402.0
Lifetime				
Ionia Ormsby Queen 1467685		267,304		8,600.4

10 Highest Yearly Butterfat Producers

Name and H.B. No.	Y.M.	Milk	Per Cent	Fat
Carnation Ormsby Butter King 1165152	8–5	38607	3.6	1402.0
Carnation Ormsby Madcap Fayne 1639621	8–4	41943	3.3	1392.4
De Kol Plus Segis Dixie 295135	9–1	33465	4.0	1349.3
Carnation Homestead Inka Mutual 1820797	7–8	34681	3.8	1333.8
Carnation Ormsby Nellie 1326284	6–2	35887	3.7	1328.8
Calamity Nig of Elmwood Farms 1560447	8–7	34616	3.8	1327.9
Carnation Ormsby Madcap 1554602	6–3	36851	3.6	1313.0
Carnation Ormsby Segis Beauty 1203395	7–8	31264	4.1	1290.4
Daisy Aaggie Ormsby 3d 571569 (V. G.)	7–5	33140	3.9	1286.2
Carnation Homestead Walker Bessie 1909671	6–6	28222	4.5	1266.0

10 Highest Yearly Milk Producers

Name and H.B. No.	Y.M.	Milk	Per Cent	Fat
Carnation Ormsby Madcap Fayne 1639621	8–4	41943	3.3	1392.4
Carnation Ormsby Butter King 1165152	8–5	38607	3.6	1402.0
Segis Pietertje Prospect 221846	6–8	37381	3.1	1159.0
Carnation Prospect Veeman 799610	8–7	36859	2.9	1070.2
Carnation Ormsby Madcap 1554602	6–3	36851	3.6	1313.0
Helm Veeman Woodcrest 486877	4–8	36218	2.8	1003.9
Carnation Ormsby Nellie 1326284	6–2	35887	3.7	1328.8
Lady Pride Pontiac Lieuwkje 849602	8–0	35627	3.3	1186.4
Kolrain Marion Finderne 317396	6–1	35340	2.9	1022.9
Alcartra Ormsby Canary 1135532	8–7	35272	3.1	1105.7

Up to July, 1948, 2,029 yearly records exceeded 25,000 pounds of milk; 204 records 30,000 pounds; and 11 records 35,000 pounds.

Herd Improvement Test. In 1928 a Herd Improvement Test was established, the results of which are published by the Superintendent of Advanced Registry in what is known as the Red Book. This Test provides that all cows in milk in the herd must be entered, and that the report must be based upon an average production per cow in the herd per year. Any cow whose record is not satisfactory may be omitted from the herd average provided the registration certificate is surrendered and no future offspring are registered. Exceptions also may be made for certain old cows. The following table, giving the summary of the Herd Test by each year, shows a rather steady increase in interest in this division.

AVERAGE PRODUCTION OF HERD TEST COWS TO OCTOBER 1, 1947

Year	Herds Tested	Cows	Milk	Per Cent Fat	Fat	Herds Over 400 Lbs. Fat
1929	242	4,834	10,864	3.37	366.4	55
1930	194	4,523	11,045	3.36	371.4	59
1931	229	4,635	10,940	3.35	366.7	64
1932	197	4,379	11,099	3.38	374.6	69
1933	204	4,716	11,256	3.44	386.8	76
1934	225	4,871	10,999	3.45	380.0	76
1935	258	5,328	11,338	3.45	391.2	116
1936	413	8,566	11,044	3.46	381.9	139
1937	493	10,517	11,210	3.45	386.5	187
1938	478	10,660	11,110	3.46	383.9	164
1939	433	10,315	11,354	3.46	393.1	168
1940	412	10,371	11,700	3.46	405.2	210
1941	442	11,285	11,859	3.46	410.0	243
1942	455	11,691	11,642	3.48	404.9	254
1943	477	11,776	11,435	3.49	399.6	233
1944	539	13,118	11,036	3.54	391.1	238
1945	681	16,396	11,071	3.52	389.3	296
1946	874	19,692	11,116	3.53	391.9	403
1947	1,080	23,926	11,119	3.54	393.4	502
Average for	8,326	191,599	11,243	3.48	391.1	3,552

Herd classification. In 1929 the Holstein-Friesian Association of America adopted a herd classification program, the first of its kind. Each animal is rated by an official inspector, appointed by the Association, into one of six type-classes as follows:

"Excellent" —range, 90 points or over
"Very good"—range, 85–90 points
"Good Plus"—range, 80–85 points
"Good" —range, 70–80 points
"Fair" —range, 60–70 points
"Poor" —range, below 60 points

Only cows that have freshened and bulls three years old are eligible for herd classification. The registration certificate is cancelled for animals

that rate "Poor" and male progeny from females classified "Fair" cannot be registered. Provision is made for reclassification of any individual after a lapse of at least nine months. The following table gives a summary of the classification work for October 1, 1946 to September 30, 1947, with the percentage found in each class.

	Females	*Males*	*Total*	*Per Cent*
Excellent	170	37	207	1.1
Very Good	2,980	252	3,232	17.2
Good Plus	8,127	291	8,418	44.7
Good	5,488	92	5,580	29.6
Fair	1,350	7	1,357	7.2
Poor	41	0	41	.2
Totals	18,156	679	18,835	100.0

Studies have revealed a fairly good correlation between type classification and milk and butterfat production. An analysis of the type classification of 16,696 cows of which 6,440 had Herd Improvement Records is given in the following table:

Class Groups	Total Females Class	No. Cows With H.I.R. Records	Per Cent With H.I.R. Records	Average No. Records Per Cow	Average Lbs. Milk	Average Per Cent Fat	Average Lbs. Fat
Excellent	511	261	51.1	3.01	17,215	3.49	601.4
Very Good	3,122	1,377	44.1	2.69	15,988	3.47	554.5
Good Plus	5,363	2,213	41.3	2.47	15,754	3.46	544.5
Good	6,283	2,138	34.0	2.27	14,960	3.43	513.6
Fair	1,300	426	32.8	2.17	14,316	3.41	488.1
Poor	117	25	21.4	1.36	12,612	3.41	430.7
Total	16,696	6,440	38.6	2.43	15,492	3.45	534.5

Recognition of sires. There are three special recognitions of sires provided for by the Holstein-Friesian Association of America. One is based upon the type of his daughters (Silver Medal Type Sire); another is based upon the production of his daughters (Silver Medal Production Sire); and the third is based upon a combination of type and production of his daughters (Gold Medal Proven Sire). The requirements for qualifying for each of these recognitions are:

Silver Medal Type Sire. A bull is entitled to this recognition if 75 per cent or more of his daughters have an average score of at least 81 points. A minimum of ten daughters must be scored. If only 50 to 75 per cent of the daughters are classified, an average score of at least 82 must be gotten. If the classified daughters range from 25 to 50 per cent of the total the score must be 83 or more and for 25 per cent or less a minimum average score of 84 points is required. In all cases a minimum of ten daughters must be classified.

If 50 per cent of his Advanced Registry or Herd Test daughters have

qualified with production 50 per cent in excess of A.R. requirements, showing not less than 3.3 per cent butterfat, with a minimum of ten so qualifying, such sire shall be designated a Silver Medal Production Sire and an appropriate certificate shall be issued.

Gold Medal Proven Sire. Whenever a sire qualifies both as a Silver Medal Type Sire and a Silver Medal Production Sire, he shall be designated as a Gold Medal Proven Sire, and an appropriate certificate shall be issued.

Chapter 12

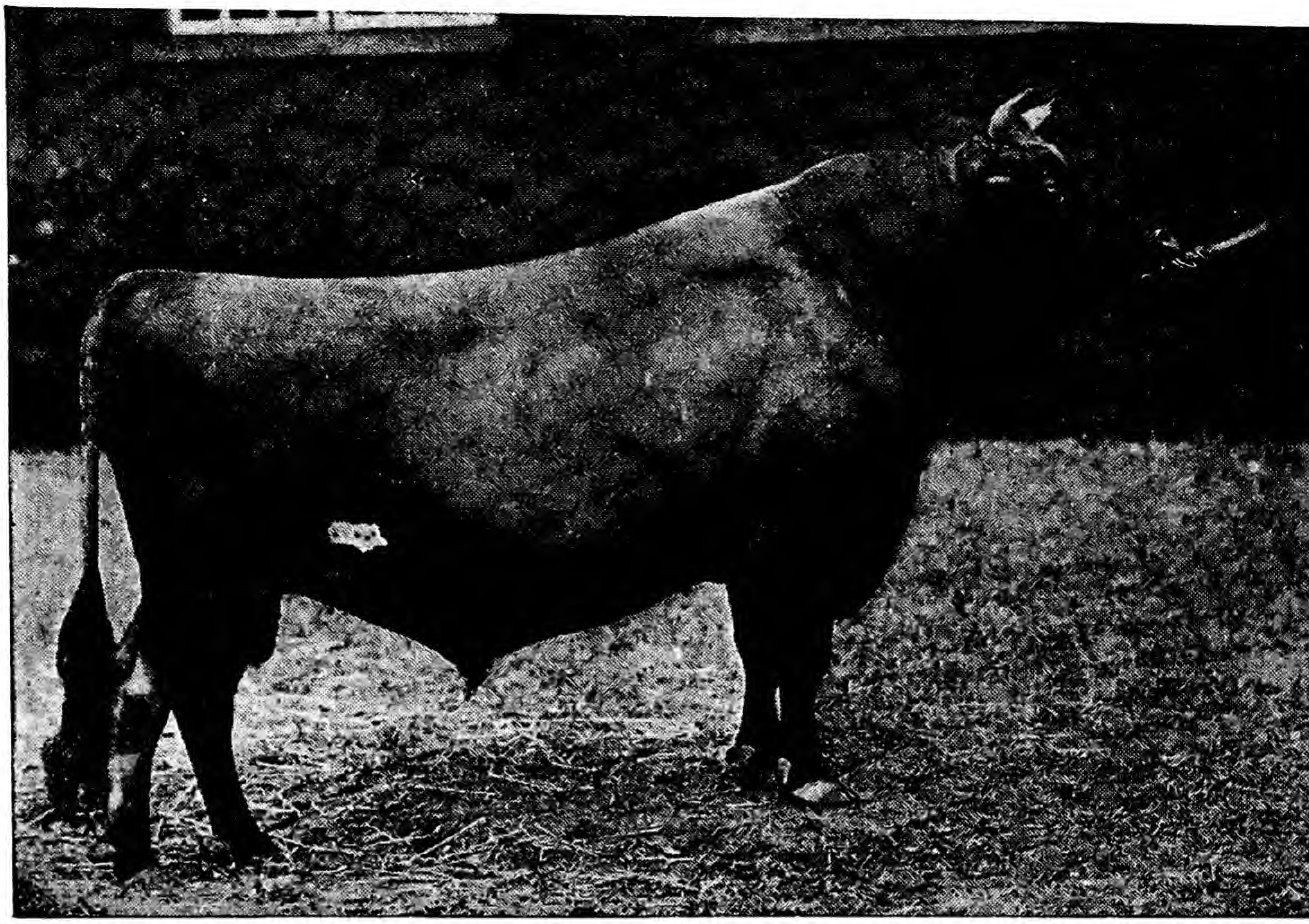
THE JERSEY

CHARACTERISTICS. EXCEPT FOR THE DEXTER AND THE KERRY, THE Jersey is the smallest of cattle. The desired weight for mature cows ranges from 900 to 1,100 pounds. The normal weight for mature bulls ranges from 1,300 to 1,600 pounds. Both cows and bulls on the Island of Jersey are, on the average, smaller than in this country. Seldom does a cow on the Island attain 1,000 pounds in weight. In this country a large number of breeders have selected for large size and, as a result, they have developed strains that breed relatively true for this character. Others have bred for the smaller type. Many people refer to the larger type as American and to the smaller and more refined as the Island type. Since many of the smaller and more refined Jerseys have been bred in this country for as many generations as the large so-called American type, these terms are unfortunate.

Type. The Jersey breed has more individuals than has any other breed that approach the classic true dairy type. The good Island type Jersey possesses more dairy character than do individuals from any other breed. The top line is straight, and the level rump is unsurpassed. The true type head possesses what is known as a double dish; that is, there is a dish between the eyes and another dish presented by a profile view. Jerseys are generally considered as having the best shaped udders and the best udder attachments. They are more angular and more free from excess fleshiness than members of other breeds. The so-called American type, in addition to being larger, is rougher and lacks the pleasing lines of the so-called Island type. (Figs. 25 and 26.)

Color. Of all breeds the Jersey is the most variable in color. Individuals may be of solid color or white spotted. Solid colored animals may be black or any shade of color from black to a very light fawn. The color may be a uniform shade over the entire body, or black spots may appear on a lighter colored background. The degree of white spotting varies greatly, ranging from a few small white spots to spotting so large that most of the body is white. The colored portion of the spotted animal may possess all the variations in shades that have been described for the solid colored animals. Some breeders are prejudiced against the black and spotted Jerseys, and select for the solid colored fawns, usually considered the most typical Jersey color. However, many black or spotted Jerseys have won the highest awards in the show ring.

The tongue and switch of the Jersey may be either white or black. In applications for registry, the colors of the tongue and switch, usually known as the points, must be stated. The muzzle is black encircled by a light-colored ring.



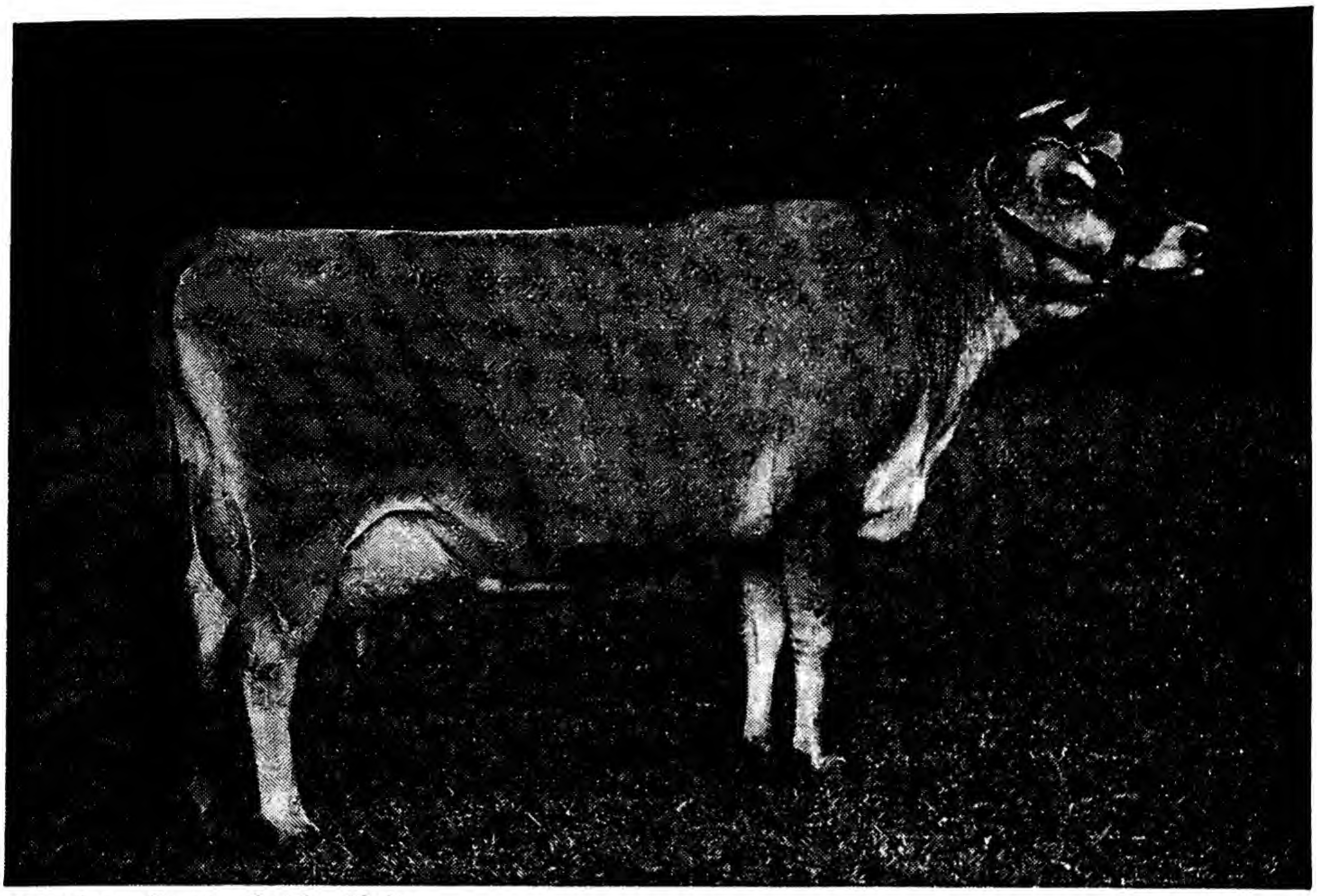
American Jersey Cattle Club

Fig. 25. Brampton Standard Sir 276574, one of the outstanding Jersey bulls of the present time. He is a Gold and Silver Medal Bull as well as a "Superior Sire," and has won many championships, as have his progeny.

Nervous reactions. The Jersey probably has the most highly developed nervous system of all the dairy breeds. Jerseys are very sensitive and react quickly to stimuli. This characteristic may be either advantageous or disadvantageous. When they are treated well, they are quick to respond favorably; but if they are mistreated, they are equally quick to respond unfavorably. The Jersey bull is more likely to be vicious than are bulls from other breeds.

Grazing ability. The Jerseys rank high as grazers. On moderate pastures the Jerseys have often been observed to do better than members of other breeds. This may be accounted for in two ways. The Jersey, because of her small size, needs less nutrients than do larger cows, and therefore will secure her requirements from smaller areas; and she is inherently active.

Reproduction and longevity. Jerseys rank high as reproducers and for long productive lives. The calves, however, are small at birth and considered rather hard to raise. The female calf averages about 55 pounds at birth, or less than 6 per cent of the weight of the dam. Bull calves average about 60 pounds at birth. The Jersey calf is not only the smallest of all calves at birth, but also represents a smaller per cent of the weight of the dam.



American Jersey Cattle Club

Fig. 26. Imp. Wonderful Snowdrop 941016 represents excellent Jersey type and high production. On Herd Improvement Registry she produced 833.5 pounds of fat and 14,234 pounds of milk. She has placed well in the leading shows of the country, including championships at state fairs and second place among aged cows at the National Dairy show.

Maturity. Jerseys are the earliest of all breeds to mature. Heifers are usually sufficiently mature to calve when 24 to 26 months of age. Many come into milk much earlier, but this is not advisable, since there is insufficient development for milk production.

Meat and veal. The Jersey is the poorest of all breeds for both meat and veal. The body fat of the Jersey is yellow in color, an objectionable feature in meat. The small size, poor fleshing, and poor distribution of the fat also contribute to make the Jersey the poorest of all breeds for either meat or veal production.

Milk. The Jersey is noted for the quality of her milk rather than for the quantity. Jersey milk is superior to all other milk in both its fat and total solids content. The butterfat in Jersey milk varies from 4 to 8.0 per cent, with an average for the breed of 5.3 per cent. The total solids content averages 14.9 per cent. The butterfat constitutes 35.5 per cent of the total solids, as contrasted to 28 per cent for the Holsteins. Because butterfat constitutes such a high percentage of the total solids, the Jersey produces butterfat at a lower cost than other breeds.

Because of the high quality, Jersey milk is more expensive to produce and must sell for a higher price. The American Jersey Cattle Club has

copyrighted the term "Jersey Cream Line" to be used on Jersey milk and lends assistance in developing special milk markets where Jersey milk sells at from two to five cents more per quart than ordinary market milk. "Jersey Cream Line" milk is marketed in all large cities.

In addition to the high fat and total solids content, Jersey milk has other distinctive features. The butterfat is high in carotene, which gives the fat a yellow color. The fat globules are the largest of any, averaging 25 per cent greater in diameter than those of the Holstein. Because of the large fat globules, the cream rises faster and churns more rapidly than does cream from other milk. The ease with which the cream churns sometimes causes difficulty in shipping milk, since the agitation is frequently sufficient to cause partial churning of the fat in the milk.

The milk from Jerseys is especially adapted for special milk markets and for butter or cream production. The fat-to-solids ratio is too high for cheese making or for producing evaporated milk.

The Jersey also ranks first in persistency.

Origin and native home. The exact origin of the Jersey is a subject of conjecture. That they are descendants from the wild species *Bos longifrons* is generally agreed upon, but as to whether they are descendants of the cattle of Brittany and Normandy, which resembled the Jersey, is a subject of controversy. They have been developed on the Island of Jersey, one of the four British Islands in the English Channel off the coast of France. The other three islands in this group are Guernsey, the home of the Guernsey cow; Sark; and Alderney. A consideration of what is known about the environment and the development of the Jersey in its homeland will help in understanding many of the Jersey characteristics.

The Island of Jersey is ten miles from east to west, with an average width of six and one-fourth miles. It slopes from north to south, and has a maximum elevation of 500 feet. Its mean temperature is 40.1° F. for January and 63° F. for August, with an average rainfall of 34.2 inches. Frost lasts for short periods only, and snow seldom more than two or three days. The climate, therefore, is mild, although a chilly, moisture-laden wind is not uncommon.

In 1931 a population of 50,455 was living on the 61.9 square miles, or an average of more than 800 people per square mile. In 1934 there were 1,764 farms, totaling 21,000 acres. Although 30 per cent of these farms contained less than 4.5 acres, 25,657 acres of crops were reported in 1934, a greater area than the total farm area. This was possible because two and even three crops may be raised annually. Early potatoes for the British market are one of the chief crops of the Island. Tomatoes rank second in importance, with greenhouse products next. Since 1867 from 10,000 to 12,000 Jersey cattle have been kept. In 1934 there were about a thousand breeders having 10,682 head, of which all but 123 were registered.[1]

The chief feed is pasture, the grasses of which grow very luxuriantly. The cows are usually tethered in a line across the field and move back

[1] Gow, R. M. *The Jersey.* American Jersey Cattle Club, New York.

and forth as the grass is eaten off. Most cows of the Island are never fed concentrates.

According to Gow, the earliest references to the cattle on the Island were made in 1734, when they were described as being "superior to the French Cattle." In 1885 the U. S. Consulate in Liverpool declared that the Jersey had been purebred for 500 years. While there is no proof of this statement, the Islanders have traditionally had pride in their cattle and confidence in their superiority over other cattle, and, therefore, have kept them purebred for a long time. In 1789 a law was passed forbidding transportation of cattle to the Island except for immediate slaughter.

The smallness of the Island and the long time during which they have been bred pure have done much to establish the Jersey characteristics. The Islander first selected for rich milk. The closeness with which cows were associated with humans (barns and houses being together) made it imperative that the animals be docile, and brought about their being responsive to good care. Because roughage has been the chief diet, if not the sole one, they had to be good roughage eaters.

On the Island the Jerseys are very uniform as to type. This is attributable to the system of registration, which requires inspection of all animals by a committee before registration. At stated periods a committee of judges will respect cattle at a given point. The owners desiring registration take the animals before the judges, where they are given a rating on the basis of type. If they meet with the approval of the judges, they are classified as commended, and a "C" is placed after the registration number. If superior, they are given a rating of highly commended, or H.C. Bulls must be accompanied by their dams at inspection. As all animals on the Island are eligible to registration whether or not now registered, an unregistered animal is given the suffix F.S. (Foundation Stock) after its registration number. All those with registered ancestry carry the suffix P.S. (Pedigreed Stock). Parish shows have been another important factor in bringing about breed uniformity and improvement. Since 1834, when the first Parish show was held, these shows have been extended to every one of the 12 Parishes. At these shows valuable money prizes are offered for bulls, and those for which money awards are received must be held for public service for one year. Bulls classed as undesirable at these shows are slaughtered.

On the Island the keeping of official records of production has never been extensive. A system similar to the American Register of Merit testing has been adopted, but it has been used comparatively little. The Jersey breeder on the Island has been more interested in type, in the belief that the right type makes for high production.

Importation and distribution. *In England.* According to Gow, Jerseys were known in England as early as 1771. The most significant importations were those made by Phillip Dauncey, who began importations in 1821. Dauncey selected the largest and most rugged Jerseys he could find on the Island and continued to breed for these characteristics in England. By inbreeding, he fixed large size, ruggedness, and high production. W. G.

Duncan bred for the same objective, and also imported stock from the Island. Many importations of stock from these herds were made to America, where the inbreeding practices of these two English breeders were continued; these herds, then, were the sources of the so-called American type. The English Jersey Cattle Society Herd Book was started in 1879. At present, there are about 900 members. The British Royal Family have been breeders of Jerseys for three generations.

In America. Because in the earlier days no distinction was made between Guernseys and Jerseys, both being called Alderney, it is impossible to determine the date of the first importation of Jerseys. In 1811 and again in 1840 Alderney cows are reported to have been imported. The first importation of definite record was made by Captain Pratt in 1850. Nine of these are registered in Volume 1 of the Herd Register. There were, however, several importations made prior to 1850 of which there are no records. It is commonly known that seamen brought over cattle with other cargo at the beginning of American trade. No doubt many of these were Jerseys. Since 1850 Jerseys have been imported continually and are still being imported; the United States health regulations permit importations from the Island of Jersey because of the freedom from disease there. During the two years 1934 and 1935, 266 Jerseys were imported. From 1850 to 1935 inclusive, 22,654 Jerseys were imported. This was 1.54 per cent of the 1,465,872 Jerseys registered by the American Jersey Cattle Club. From 1935 to 1948 an additional 3,475 head were imported.

Quite a number of Jerseys were imported from England before the Jersey Cattle Club in 1875 stopped such importations. In 1900 this rule was rescinded by the membership, and since then a few Jerseys have been imported; but the disease situation in England has interrupted this trade. The foundation animals of the St. Lambert family were imported from England, coming from the W. G. Duncan herd there.

Jerseys are found in every state of the Union. In numbers of Jerseys, the leading states rank as follows: Ohio, Texas, New York, Pennsylvania, Missouri, Kentucky, and Tennessee. In general, Jerseys are most numerous in the South and East and in Oregon on the Pacific Coast. In the early '80's a Jersey cow sold for $25,000. This gave a great impetus to the Jersey breed, as did the winning of the dairy tests in the World's Fair in Chicago in 1893, and again in St. Louis in 1904. During the boom following World War I, the prices for Jerseys did not advance as much as for some other breeds, nor did they drop as much in the depression period.

Jerseys are found in practically every country in the world, but they are the most numerous in the United States and England.

Families. No other breed has as well-defined families as the Jersey. While there have been intercrossing of families, the Jersey breeders have practiced linebreeding and inbreeding to a greater extent than is found in any other dairy breed. Most of the Jersey families trace back to a bull for the foundation animal, whereas the foundation animal of a Holstein family, for example, is usually a cow. There are so many families and subfamilies in the Jersey breed that space forbids mention of all of them.

Of the American type the St. Lambert, Sophie Tormentor, Golden Glows, and the St. Mawes are the most prominent families. Another prominent family is the Golden Ferns, of which Golden Fern's Lad is the foundation sire. He is said to have had a greater influence upon the breed than any other bull. The Golden Jolly, Flying Foxes, Eminent, Noble, Raleigh, Majesty, Sybil, Fauvic Prince, and Golden Glow families trace back to Golden Fern's Lad or his grandsire, Golden Lad. The Owl-Interest Blonde, Volunteer, and Design Families are also very prominent.

Registration. All records of Jerseys are kept by the American Jersey Cattle Club, with offices in Columbus, Ohio. This club, organized in 1868, publishes the herd book known as the Herd Register of the American Jersey Cattle Club. Until 1882 registering Jersey cattle and publishing the herd books were the only functions of the American Jersey Cattle Club. Since that time, the organization has taken over the supervision of official testing and breed promotion work. At the present time the American Jersey Cattle Club employs several field men for promoting the interests of the breed.

Up to April, 1948, approximately 1,646,000 females and 500,000 males have been registered. In 1947 a total of 81,123 animals were registered. During the depression years the number of registrations declined to the low of 35,000 in 1933.

In order to be eligible to register in the herd books of the American Jersey Cattle Club, animals must have registered parents, or when imported, be registered or eligible to registry in the Island, Canadian, or English herd books. Before an application for registry can be made, the animal must be tattooed with a suitable mark in the ear.

Testing. The administration and recording of official production records is a very important function of the American Jersey Cattle Club. The system is known as the Register of Merit. The American Jersey Cattle Club began the supervision of tests in 1884 when they authorized 7 day butter tests to be made under the supervision of the Club. Prior to that, records made privately have been published, the first of which was made in 1853 when the cow, Flora, was credited with 511 pounds and 2 ounces of butter in 350 days.

The first authenticated tests were published in 1889. In order to qualify for entrance to the list, a cow must produce 14 pounds of butter in seven days. All of these early records were made privately and reported under oath to the Cattle Club. In 1891 the tests were extended to include records of any length above seven days, thus making the system absurd, since owners reported on all possible lengths of test periods. In 1902 the Club voted to accept seven day tests authenticated by colleges, and in 1903 it established the Register of Merit system, which has undergone many changes down to this date; but it required from the beginning authentication by experiment stations for acceptance. Private tests were accepted up to 1911; and in 1919 short-time tests were dropped.

There are now two types of records accepted—the Register of Merit Tests, and the Herd Tests. Both of these tests are conducted under the

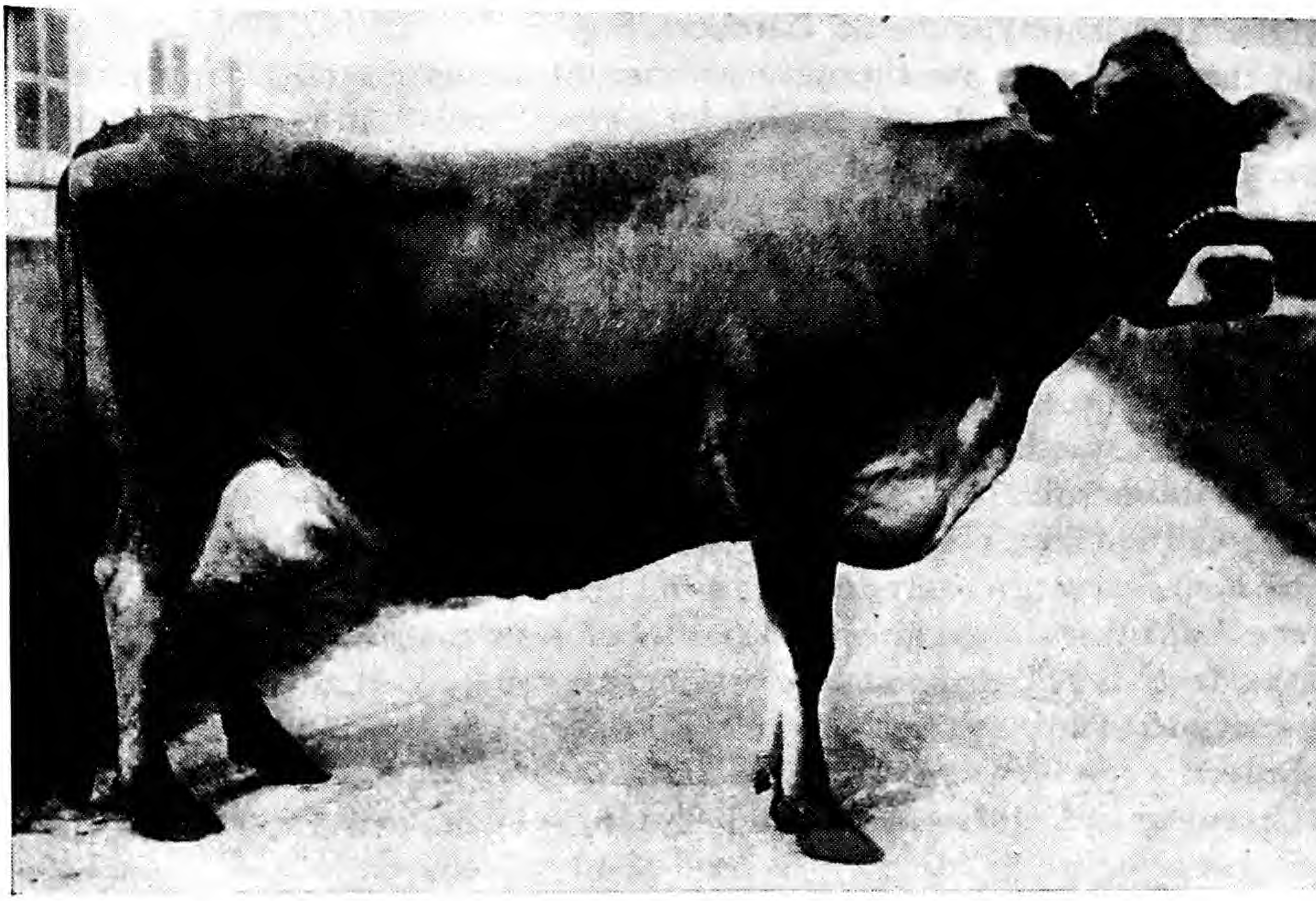


Fig. 27. Silken Lady's Ruby of F. 919141 has the lifetime butterfat production record over all breeds.

supervision of the Superintendent of Official Testing of the various states.

Register of Merit. The Register of Merit has three classes, with requirements as follows:

Class A: To be eligible to Class A, a cow must produce 290.5 pounds of fat as a two year old, or 400 pounds of fat when mature.

Class AA: To be eligible to this class a cow must meet the production requirements for 365 days and, in addition, give birth to a living calf carried not less than 155 days during the test.

Class AAA: To be eligible to this class a cow must produce in 305 days at least 250.5 pounds of fat as a two year old and 360 pounds of fat as a mature cow, and give birth to a living calf within 13 months from the previous calving.

Discarding all short-time records, 76,862 production records have been accepted by the Club up to March 31, 1948. These records are divided as follows:

Kind of Test	Number of Tests	Average Milk	Average Fat	Average Fat
		Pounds	*Pounds*	*Per Cent*
305 days...........	35,743	8,203	438.2	5.34
365 days...........	41,119	9,037	485.3	5.37

In 1942, there was established an award known as Lifetime Butterfat Champion, to be given each year. Three cows have won that award up to and including 1947, as follows:

Year Awarded	Name of Cow	Milk (Pounds)	Fat (Pounds)
Initial	Radiant Romance Storrs 587210	154,327	7,706
1942	Daisy Gray Fern 868266	114,101	6,251
1943	Silken Lady's Ruby of F. 919141	122,280	6,654
1944	Silken Lady's Ruby of F. 919141	133,180	7,242
1945	Silken Lady's Ruby of F. 919141	146,236	7,975
1946	Silken Lady's Ruby of F. 919141	155,988	8,550
1947	Silken Lady's Ruby of F. 919141	166,020	9,165

Silken Lady's Ruby of F. still producing at 18 years of age has the highest lifetime butterfat production record of all breeds at any time.

The butterfat champions for each of the recognized age groups in both the 305 and the 365 day divisions as of July 1, 1948 are presented in the following tables:

NATIONAL 365 DAY BUTTERFAT CHAMPIONS

Class	Name and H.R. Number	Class	Milk	Per Cent Fat	Fat	Age
Yr.	St. Mawes Lad's Lady 451568	A	11,756	7.05	829.08	1–11
Jr. 2	Raleigh's Toron'os Meme 544207	A	16,085	5.61	902.15	2–5
Sr. 2	Viola's Rinda Fancy 716673	A	12,738	7.38	939.96	2–10
Jr. 3	Poppy's Dortha 378520	A	17,804	5.58	994.25	3–4
Sr. 3	Welcome Volunteer Tiff 1316589	AA	19,416	5.55	1,076.80	3–11
Jr. 4	Darling's Jolly Lassie 435948	AA	16,425	6.95	1,141.28	4–0
Sr. 4	Vive La France 319616	AA	14,926	6.91	1,031.64	4–7
Over 5	Stockwell's April Pogis of H. P. 694544	AA	17,880	6.81	1,218.48	8–3
Over 12	Silken Vive Glow Dinah 905153	A	17,336	5.88	1,018.77	12–2

NATIONAL 305 DAY BUTTERFAT CHAMPIONS

Class	Name and H.R. Number	Class	Milk	Per Cent Fat	Fat	Age
Yr.	The Lion's Lilac 671092	AAA	10,752	6.91	742.44	1–9
Jr. 2	Tristram Basil Cleo 1465209	A	13,482	5.32	717.87	2–3
Sr. 2	Sybil Tessie Lorna 996685	AAA	15,357	5.63	865.07	2–10
Jr. 3	Volunteer Bell Rosalie 1178965	A	14,177	6.07	861.16	3–5
Sr. 3	The Lion's Lilac 671092	AAA	13,844	6.69	926.55	3–11
Jr. 4	Dairylike Maid Cleo 1131609	AAA	15,303	6.36	972.69	4–5
Sr. 4	Fon Sayda 704373	A	13,020	6.53	850.56	4–6
Over 5	Missionary Noble Alice 1199012	AAA	19,390	5.35	1,038.03	8–5
Over 12	Gilsland B. Foxy Poetess 991549	A	13,757	6.02	827.60	12–3

The Herd Test. In 1928 rules were adopted for Herd Improvement Registry. This test may be conducted in conjunction with Register of Merit testing. All tests are under the supervision of the State Superintendent of Official Testing. The test covers 365 days, and the butterfat periods without preliminary milkings, or bimonthly 24 hour official test

periods with preliminary milking. All registered cows in milk in the herd must be tested. The latter feature is one which prevents selecting the good cows for test and leaving out the poor ones. A certificate is issued by the Club giving the number of cows tested, and the average milk and butterfat production with the average fat percentage. Individual lactation certificates may also be had. Up to April 1948, this test had been elected for 5,433 herds with a total of 145,659 cows. These averaged 375.9 pounds of fat, 7,036 pounds of milk, and a fat percentage of 534.

Awards. In addition to a Register of Merit Certificate, cows that meet certain specifications are awarded medals or special certificates. Only one of each medal can be awarded a breeder. For subsequent animals that qualify, appropriate certificates are furnished.

A Medal of Merit is issued for each cow producing 740 or more pounds of fat in Class AAA, or 850 or more pounds of fat in Class AA. Bulls having three or more Medal of Merit daughters out of different dams qualify as Medal of Merit bulls. A Gold Medal is issued for cows producing between 610 and 730 pounds of fat in Class AAA and between 700 and 849 pounds of fat in Class AA. A bull having three Gold Medal daughters out of different dams qualifies as a Gold Medal bull.

Silver Medals are awarded to cows under five years of age producing 410 pounds of fat in Class AAA and 500 pounds of fat in Class AA at two years of age, with increased requirements of .2 pounds of butterfat for each day older than two years. A bull having three or more Silver Medal daughters qualifies as a Silver Medal bull.

Bulls are given a Superior Sire award when the following requirements are met:

1. At least ten daughters have completed lactation periods of 270 days either in Register of Merit or Herd Improvement Registry.
2. More than 50 per cent of all registered daughters four years old or over are tested.
3. The average butterfat production exceeds 600 pounds of fat on a mature basis.
4. At least ten daughters have been classified, and the average score for all daughters classified is 82 or more.

Ton of Gold Certificate. Any cow producing 2,000 pounds of butterfat or more in four consecutive 365 day herd test periods is entitled to a certificate known as the Ton of Gold Certificate.

Gold Star Herd Award. This award is a recognition for continuous meritorious production. To qualify, herds in Herd Improvement Registry must average annually for four consecutive years not less than the following for herds of different sizes:

Size of Herd	Minimum Annual Av. Butterfat *Pounds*
5 to 10 cows	475
11 to 50 cows	450
Over 50 cows	425

Tested Sire. Any bull having ten or more daughters having completed records in either Register of Merit or Herd Improvement Registry is known as a tested sire.

Constructive Breeder's Certificate. This award is regarded as the highest recognition of the American Jersey Cattle Club. To qualify for this award the following requirements must be met:

(1) The herd must be re-entered on H.I.R. and have completed an average of 400 pounds fat if 10 cows, and 340 if 40 cows or more.
(2) A total of 50 per cent of animals in the herd that ever calved must have been bred by the owner; 65 per cent must have been bred or owned at least four years at the date of qualification.
(3) At least 60 per cent of all animals in the herd must have been officially classified with a minimum average of 82.00 per cent at the date of qualification.
(4) The herd shall be federally T. B. Certified.
(5) The herd shall be Bang's-free or certified by the state veterinarian to be in process of Bang's eradication.
(6) The breeder must show evidence of membership in his state or local club.

Star Bull Award. This scheme is an attempt to evaluate bulls before they are proven by rating the performance of the ancestors. One star will be awarded for each five credits provided that not over two-thirds of the credits can come from either the top or the bottom half of the pedigree. A bull may obtain as many as seven stars but to qualify for four or more stars at least three credits must come from classification. The following table shows how credits are obtained.

TABLE LISTING CREDITS FOR STARS

Sire

Having 10 or more tested daughters averaging:
360 lbs. fat merits 1 credit
390 lbs. fat merits 2 credits
420 lbs. fat merits 3 credits
450 lbs. fat merits 4 credits
480 lbs. fat merits 5 credits
510 lbs. fat merits 6 credits
540 lbs. fat merits 7 credits

Having 10 or more officially classified daughters averaging:
81 per cent merits 2 credits
82 per cent merits 3 credits
84 per cent merits 4 credits

(Transmitted Credits)

A 2 Star Bull may transmit 2 credits.
A 3 Star Bull may transmit 4 credits.
A 4 or more Star Bull may transmit 5 credits.

Paternal Grandsire

Having 10 or more tested daughters averaging:
420 lbs. fat merits 1 credit
450 lbs. fat merits 2 credits

Having 10 or more officially classified daughters averaging:
81 per cent merits 1 credit
82 per cent merits 2 credits

Paternal Grandam

Having 3 or more tested progeny averaging:
420 lbs. fat merits 1 credit
450 lbs. fat merits 2 credits

Dam

Having a 2 x 305 M-E production record of:
390 lbs. fat merits 2 credits
450 lbs. fat merits 3 credits
510 lbs. fat merits 4 credits
"Ton of Gold" or Owner's
Notice of its equivalent,
merits 5 credits (in place of
individual lactation record)

Having an official classification of:
"Good Plus" merits 2 credits
"Very Good" merits 3 credits
"Excellent" merits 4 credits

Having 3 or more tested progeny averaging on the 2 x 305 M-E basis:
360 lbs. fat merits 1 credit
390 lbs. fat merits 2 credits
420 lbs. fat merits 3 credits
450 lbs. fat merits 4 credits
480 lbs. fat merits 5 credits
510 lbs. fat merits 6 credits

Maternal Grandsire

Having 10 or more tested daughters averaging:
420 lbs. fat merits 1 credit
450 lbs. fat merits 2 credits

Having 10 or more officially classified daughters averaging:
81 per cent merits 1 credit
82 per cent merits 2 credits

Maternal Grandam

Having 3 or more tested progeny averaging:
420 lbs. fat merits 1 credit
450 lbs. fat merits 2 credits

Herd classification. With the objective of improving the type of the Jersey, the American Jersey Cattle Club in 1932 adopted a plan for classifying animals in a herd on the basis of type. The classification is made by judges approved by the American Jersey Cattle Club. Animals are to be classified into six groups according to conformation on the basis of score as follows: excellent, if scored 90 or more points according to the official Scale of Points; very good, if scored 85 to 90; good plus, if scored 80 to 85; good, if scored 75 to 80; fair, if scored 70 to 75; and poor, if scored under 70.

Certificates giving the classification of each animal are furnished the owners. In making application for Herd Classification the applicant must agree to surrender for cancellation the certificates of all animals classifying "Poor," and the registration of future progeny of such an individual is prohibited. He must further agree not to register any male calves from cows rating "fair."

Up to April 1948, 91,848 Jerseys had been classified with the following distribution in each of the classes.

Class	*Number*
Excellent	2,431
Very Good	25,364
Good Plus	42,981
Good	18,418
Fair	2,594
Poor	60
Total	91,848

Up to April 1944, 14,147 had been classified that also had records of production. The average butterfat production calculated to a 305 mature equivalent base is given for each class as well as the numbers as follows:

Class	Number	Average Fat
		Pounds
Excellent....	801	483
Very Good..	4,213	460
Good Plus...	6,060	448
Good.......	2,700	434
Fair........	369	420
Poor........	4	425

It is of special interest to note the significant decrease in average fat production with each drop in classification grade except for the "Poor" in which the number is too small to be significant.

Chapter 13

THE GUERNSEY

CHARACTERISTICS. GUERNSEY COWS VARY IN WEIGHT FROM 800 TO 1,400 pounds, with 1,100 pounds as the preferred weight. Bulls vary from 1,200 to 2,200 pounds, with 1,700 pounds as the preferred weight. The Guernsey cow, being a near relative of the Jersey, resembles her in many respects. The Guernsey, however, in addition to being larger than the Jersey, is somewhat coarser and does not possess quite the straight lines and symmetry. The udders of Guernseys are good but a little less symmetrical than those of the Jersey. The head is double dished but to a less degree than on the Jersey. Some of the more serious circticisms of the Guernsey are its weakness over the loin, roughness over the rump, and lack of symmetry of the udder. (Figs. 27 and 28.)

Color. The Guernsey varies in color from an almost red to a very light fawn, with various sizes of white markings always present. The white markings are usually found on the face, legs, flank, and switch; the rest of the body is predominantly colored. The white spotting, however, may be found on any part of the body. The preferred color of the nose is a cream or buff color. A black or smoky color of the nose is frequently found due to a factor for skin pigment that is present in the breed extensively. The skin of the Guernsey is generally highly pigmented with the yellow carotene. This is noticed particularly inside the ears, on the udder, and at the end of the tail.

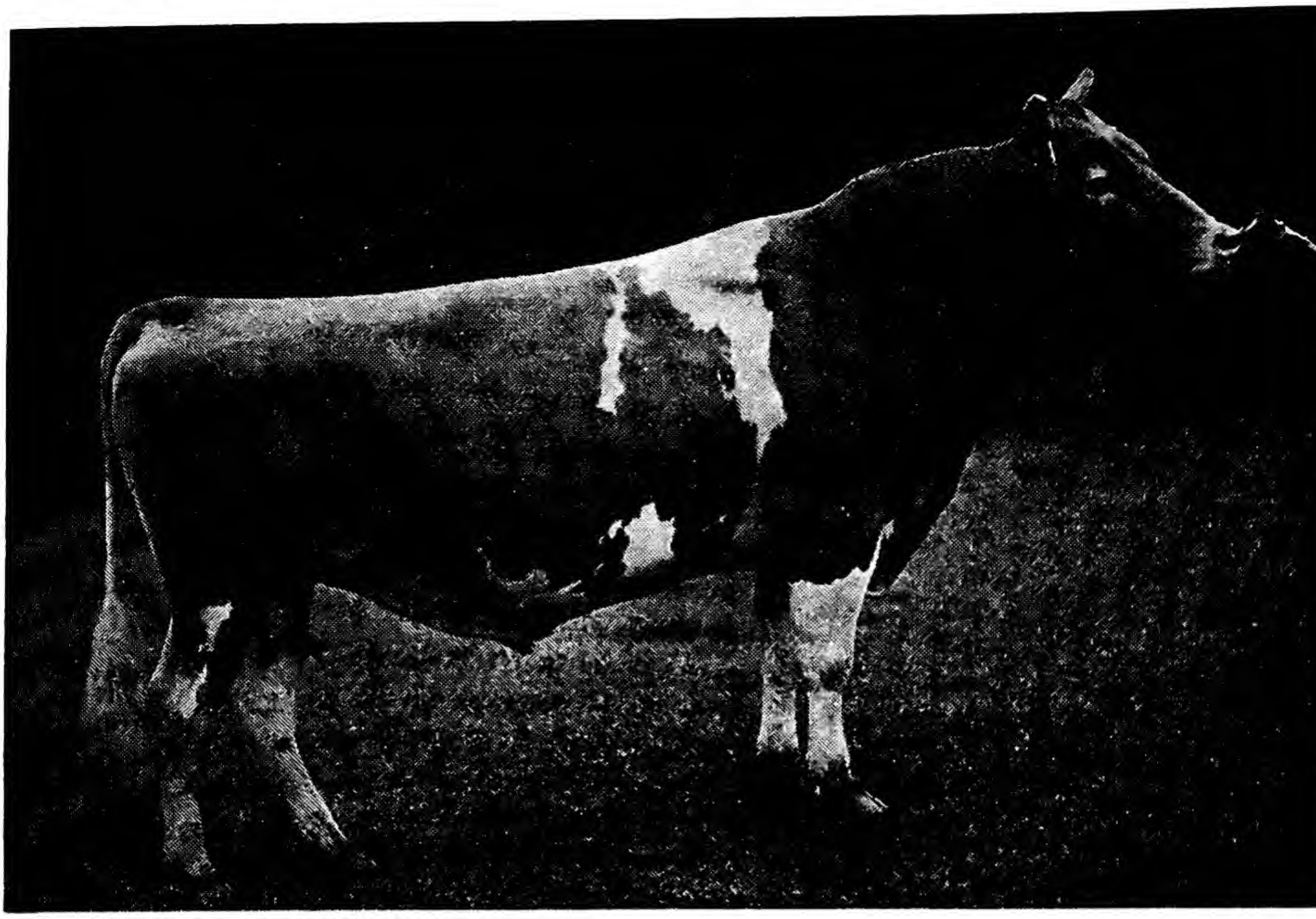
Nervous reactions. The Guernsey has excellent nervous development. She is alive and alert, yet not so easily excited as the Jersey.

Grazing. The Guernsey is not so good a grazer as the Jersey, particularly on poorer pastures. This, no doubt, is due to the larger size of the Guernsey and the correspondingly greater feed requirements.

Maturity and reproduction. On the average the Guernsey matures about two months later than the Jersey. Heifers come into milk when 26 to 28 months of age. In longevity the Guernsey ranks average, although individuals have reached as high as 20 years of age. As reproducers they also rank average. The calves average about 75 pounds at birth, or approximately 7 per cent of the dam's weight. The calves are, as a rule, not strong when born, and are usually regarded as somewhat difficult to raise.

Meat and veal. For either beef or veal, the Guernsey ranks low. The body fat is extremely yellow in color; this is highly objectionable for beef and veal. The Guernsey also lacks the desired scale and thickness of fleshing that is essential for good beef.

Milk. One of the outstanding characteristics of Guernsey milk is its high yellow color. The Guernsey possesses the ability to secrete a large proportion of the carotene pigment of the feed she consumes into the milk. The American Guernsey Cattle Club has taken advantage of this character



American Guernsey Cattle Club

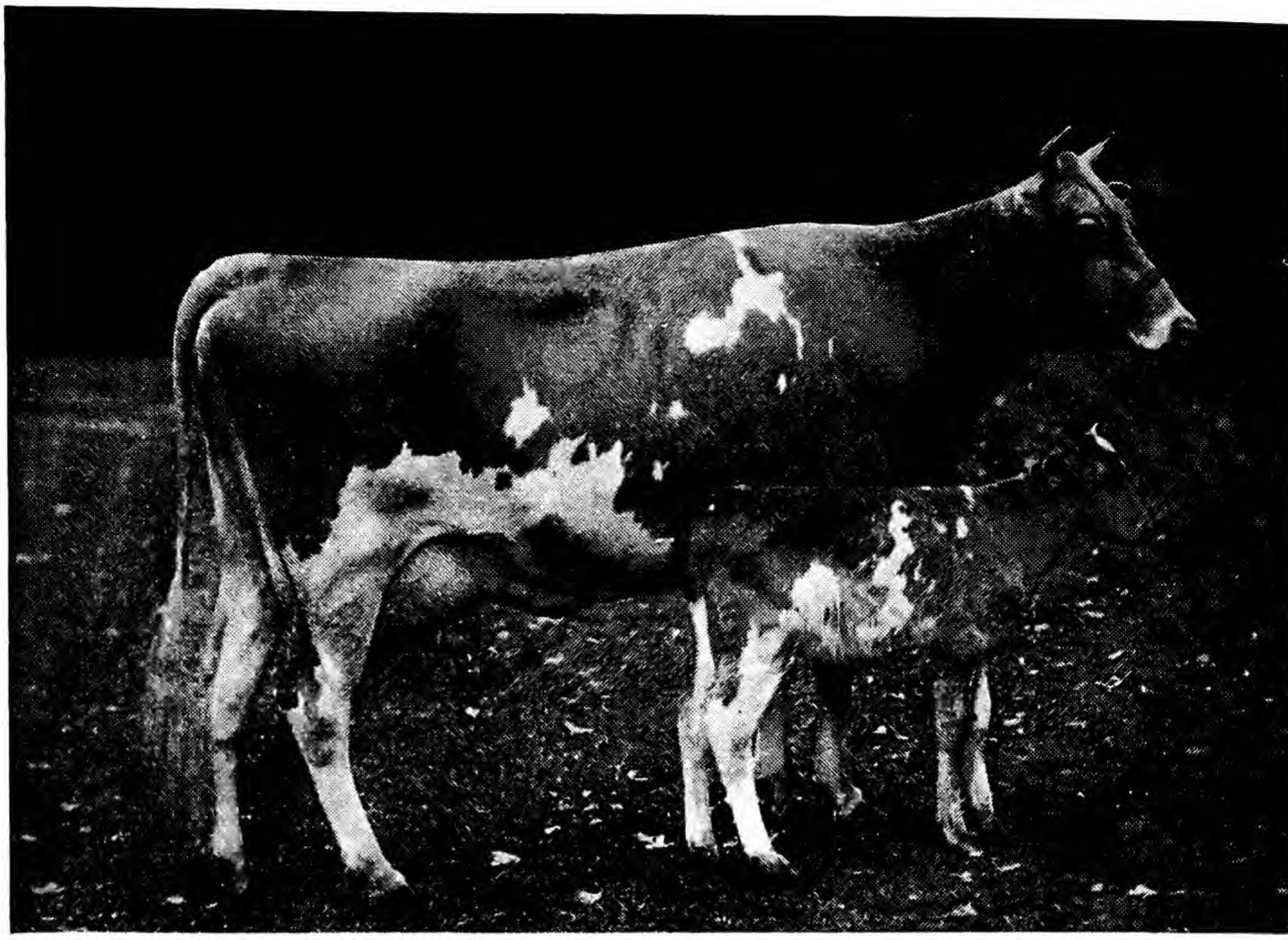
Fig. 28. A representative Guernsey bull, Green Meadow Coronation King 109429. He is the sire of 25 Advanced Registry daughters, including Green Meadow Melba, the world's record two year old Guernsey cow.

and has copyrighted the trademark "Golden Guernsey" for Guernsey milk. By advertising, the Association has created a sizable demand for this milk, and many Guernsey breeders have secured a fine market for their product at a premium price.

With a fat content of 4.98 per cent, the Guernsey milk ranks next to that of the Jersey. The average total solids are 14.49 per cent, sugar 4.98 per cent, and protein 3.84 per cent. The fat, particularly when the cows are on grass, is so highly colored with the carotene pigment that it is objectionable for the butter market. The fat particles, like those of the Jersey, are large and churn easily when the milk is in transit. With the fat constituting 33.3 per cent of the total solids, the milk is not adapted for cheese making or condensed milk. Because of this, however, they rank with the Jerseys as producers of low cost butterfat.

Home and origin. Being descendants of *Bos longifrons*, the Guernsey is of the same original stock as the Jersey. Foundation stocks are supposed to have been brought over to the Island of Guernsey from Brittany and Normandy, although there is no proof that such is the case. Hill [1] says he has evidence that both Jerseys and Guernseys were taken to the Island of Alderney and that cattle were brought from Alderney back to the Island of Jersey and possibly Guernsey. The home of the Guernsey is the

[1] Hill, Chas. L. *Guernsey Breed.* Waterloo, Iowa.



American Guernsey Cattle Club

Fig. 29. Green Meadow Melba and her calf. Green Meadow Melba holds the world's record for 2-year-old Guernseys with 15,347.9 pounds of milk and 963.9 pounds of butterfat.

Island of Guernsey, a sister island to the Island of Jersey. It is 22 miles northwest of Jersey and 15 miles from the coast of France. Its greatest length is nine miles and its greatest width is five miles. It has an area of only 24 square miles, or approximately 16,000 acres, 25 per cent of which is not tillable. The conditions on the Island of Guernsey are practically the same as those on the Island of Jersey except that the climate is slightly colder, since the slope is toward the north. The population is about 50,000, or more than 2,000 per square mile. The chief crops are flowers and garden truck, much of which is grown under glass.

There are only about 8,000 cattle on the Island. They are found mostly in small herds of from two to seven cows. The cows are tethered as they are on the Island of Jersey; and, also as on Jersey, they are fed largely upon roughage. While gardening is the chief occupation of the inhabitants of the Island, the cattle have been highly valued for a long time. In 1824 laws were passed forbidding the importation of cattle except for immediate slaughter. In 1830 a "Scale of Points" was adopted, and from that time on great improvement in uniformity of the breed has been noted. In 1879 the first Herd Book, to which all cattle on the Island were eligible for registry, was established. In 1911 the Royal Guernsey Agricultural and Horticultural Society set up an Advanced Registry system patterned after the system of the American Guernsey Cattle Club. In 1881 the first

local show on the Island was held. From that time to 1912, foundation cows admitted to the Herd Book carried the connotation C. (Commended), H.C. (Highly Commended), or V.H.C. (Very Highly Commended). After 1912 all cows were admitted and marked "Qualified at a local show."

According to Hill [1] many Alderney-bred cattle were brought to Guernsey and entered in the Herd Book there. This author also states that many cattle brought to America and England from Guernsey came originally from Alderney. Now all Alderney cattle are eligible to registry in the "Herd Book of the Bailiwick of Guernsey." The cattle from Sark and Hern are also registered in the Guernsey Herd Book. No bull on the Island can be stood for service until he is 15 months old and has been taken to a local show with his dam and approved by the Herd Book committee.

Importation and distribution. Just when the first Guernseys were brought to America is not known. In 1818 cattle called Alderneys were brought to Pennsylvania. At that time, however, no distinction was made between Guernseys and Jerseys; therefore it is not known whether these were Guernseys. According to Hill, the first importations that were kept pure were made by a Mr. Price of Massachusetts in 1830 or 1831. Descendants from these have been registered by the American Guernsey Cattle Club. Another importation was made in 1840 by a Mr. Biddle of Pennsylvania. Heavy importations began during the '80's and still continue, since Guernsey Island is free of diseases against which the United States government has established quarantines. To date there has been imported a total of approximately 113,000 head.

Since 1877 the importations by decades are as follows:

1877 to 1887	921
1887 to 1897	318
1897 to 1907	813
1907 to 1917	6,250
1917 to 1927	3,852
1927 to 1937	639

No importations were made from 1937 to 1948.

The Guernsey outside its Island home is found mainly in England and the United States. In England they have been owned and developed mainly by the nobility. In the United States they are found mostly in the East and in the North. The leading states, listed according to the number of Guernseys, are Wisconsin, Pennsylvania, New York, Ohio, Michigan, and Minnesota.

The Guernsey has increased continuously in popularity in this country. During the depression the Guernsey prices were maintained much better than those of any other breed. The demand comes from butter-producing and market-milk areas. The demand that has been built up for the yellow

[1] *Ibid.*

colored milk has been a large factor in Guernsey development around large population centers.

Families. The Guernsey has no definite families, although many outstanding foundation animals have been credited with founding families. With the exception of May Rose 2nd, who may be considered the founder of the May Rose family, none of the blood of the great foundation animals has been concentrated enough to be classified as a family.

Registration. The records of Guernseys are kept by the American Guernsey Cattle Club, with offices at Peterborough, New Hampshire. The Club was organized in 1877 and therefore is younger than either the Holstein or the Jersey organizations. At first the American Guernsey Cattle Club was concerned only with the registration and transferring of Guernsey Cattle and the publishing of the Herd Books. In 1903 the Association inaugurated supervision over Official Testing; following this they gradually developed educational and promotional work until today the work done for the promotion and development of a breed and its product by the American Guernsey Cattle Club is unexcelled.

There are 3,560 active members and more than 38,000 breeders registering cattle with the American Guernsey Cattle Club in 1948. Over 428,000 males and 1,000,000 females have been registered since the beginning of the organization. During the depression years the decline in the numbers of Guernseys registered was less than for other breeds. Since then the numbers registered have increased each year.

Testing. While comparatively little testing was done by the earlier breeders of Guernsey cattle, remarkable development has taken place in this work until there are more yearly official records on Guernseys than on any other breed. The first private record of an Alderney cow was made in 1818. This was a seven day test of 14 pounds of butter. A second private record of 14 pounds and five ounces of butter in seven days was reported in 1860. Following 1860 to 1898, a total of 160 private weekly butter tests was published by the American Guernsey Cattle Club. This is but a small number when compared with the tests reported for Jerseys and Holsteins, but the people in whose hands the Guernseys were at this time were not interested in production records.

In 1898 churn tests for yearly records were adopted. In 1901 the Advanced Register was adopted, accepting both seven day and yearly records. Both minimum fat and milk production requirements were specified as qualifications for entry in the Advanced Register. A two year old must produce 250.5 pounds of fat and 6,000 pounds of milk to qualify. Additional production was required with age increments; the minimum requirements for a five year old were 360 pounds of fat and 10,000 pounds of milk. Both the seven day tests and the milk requirement for long-time tests were soon dropped, and all efforts were then concentrated on long-time testing.

The American Guernsey Cattle Club was the first breed association to adopt long-time tests only. For many years this association had a unique system for designating the age and class of record.

The first seven letters of the alphabet were used to designate the age at which the record was made. A indicated the age of 5 years or over; B, 4½ to 5 years; C, 4 to 4½ years; D, 3½ to 4 years; E, 3 to 3½ years; F, 2½ to 3 years; and G, 2 to 2½ years.

Single letters designated a record made in 365 days without any calving requirement.

Double letters—AA, BB, etc.—designated 365 day records in which the cow carried a calf for 200 days.

Triple letters—AAA, BBB, etc.—designated records of 305 days in length, that the cow carried calf for 175 days or more, and that she was milked not more than twice daily. When milked three times daily four letters were used.

A fourth class of records is open to Guernsey breeders in the Herd Improvement Test. This test is similar to the Herd Test of the Holstein and Jersey breeds.

Designation of kind of record. Beginning January 1, 1947 the American Guernsey Cattle Club adopted a new method of designating the Advanced Registry Records. The new system gives the year in which the record was started, age of the cow including whether a junior or senior, the division in which the record is entered, the total number of milkings, the milk record, and the fat record. If the age is preceded by Jr., the record was begun before the cow was six months over the year indicated and if preceded by Sr. that she was six months or more over the indicated years. In the Division whether the record 365 days or 305 days is indicated. If the requirements are met this is followed by a *C* to indicate that a cow has carried a calf for at least 175 days in the 305-day division and 200 days in the 365-day division.

The rate with which testing has increased is illustrated by the following figures giving the total number of these tests made by ten year periods:

Period	Number of Records	Average Butterfat
		Pounds
1901–1917......	5,776	443.9
1917–1927......	17,747	497.6
1927–1937......	23,231	519.6
1937–1947......	65,604	——

A total of 112,358 records were made up to 1948. It will also be noted that there has been a consistent improvement of the production records from an average of 443.9 pounds of fat in the period up to 1917 to 519.6 pounds of fat for the 10 year period ending in 1937. The average production for the last 10 year period is not available.

The following table presents the number of records and the average milk, butterfat, and fat percentage for each of the four divisions as of June 1, 1948:

Length of Record (Days)	Carried Calf (Days)	Times Milked	Number of Records	Milk Pounds	Butterfat Pounds	Butterfat Per Cent
365.....	200	—	29,302	10,716	532	4.9
365.....	—	—	57,860	10,560	522	4.9
305.....	175	2X	26,135	8,080	396	4.9
305.....	175	3X	1,754	9,834	475	4.8

The highest milk and butterfat producers for each of the four divisions are as follows:

365-day, no calving requirement.

Milk record: Murne Cowan; 8 yrs. '15. 24,008 pounds milk and 1,098 pounds fat.

Butterfat record: Cathedral Rosalie; 5 yrs. '37. 23,714 pounds milk and 1,213 pounds fat.

365-day, carrying calf 200 days.

Milk and butterfat record is held by Flying Horse Royal Rose 5 yrs. '47. 22,558 pounds milk and 1,154 pounds fat.

305-day, carrying calf 175 days, 3X milking.

Milk record: Guernsey Goodwill, 6 yrs. '47. 19,634 pounds milk and 861 pounds fat.

Butterfat record: Sister Sue of Green Acres, 5 yrs. '48. 16,077 pounds milk and 900 pounds fat.

305-day, carrying calf 175 days, 2X milking.

Milk and butterfat record is held by Elm's Barbara Rose, 6 yrs. '48. 17,844 pounds milk and 869 pounds fat.

The lifetime production record is held by Caumsett Ida with 194,280.9 pounds milk and 8,513.5 pounds fat.

Herd classification. The Guernsey Breed was the last of the major dairy breeds to adopt Herd Classification. This endeavor was inaugurated on March 1, 1947, and up to July, 1948, 14,000 individuals had been classified. The classification judge is a full-time employee of the American Guernsey Cattle Club.

Chapter 14

THE AYRSHIRE

CHARACTERISTICS. THE AYRSHIRE IS A LITTLE LARGER THAN THE GUERNSEY. Cows should weigh between 1,100 and 1,400 pounds, and bulls between 1,700 and 2,300 pounds. The Ayrshire is noted for its beauty of form. No breed excels it in general style, straightness of top line, levelness of the rump, and symmetry of the udder. Great emphasis has always been laid upon the shape of the udder, and as a result, the Ayrshire is unexcelled in this respect. In recent years the phrase "Vessel Type Ayrshire" has been used to designate cows with this specially desired characteristic.

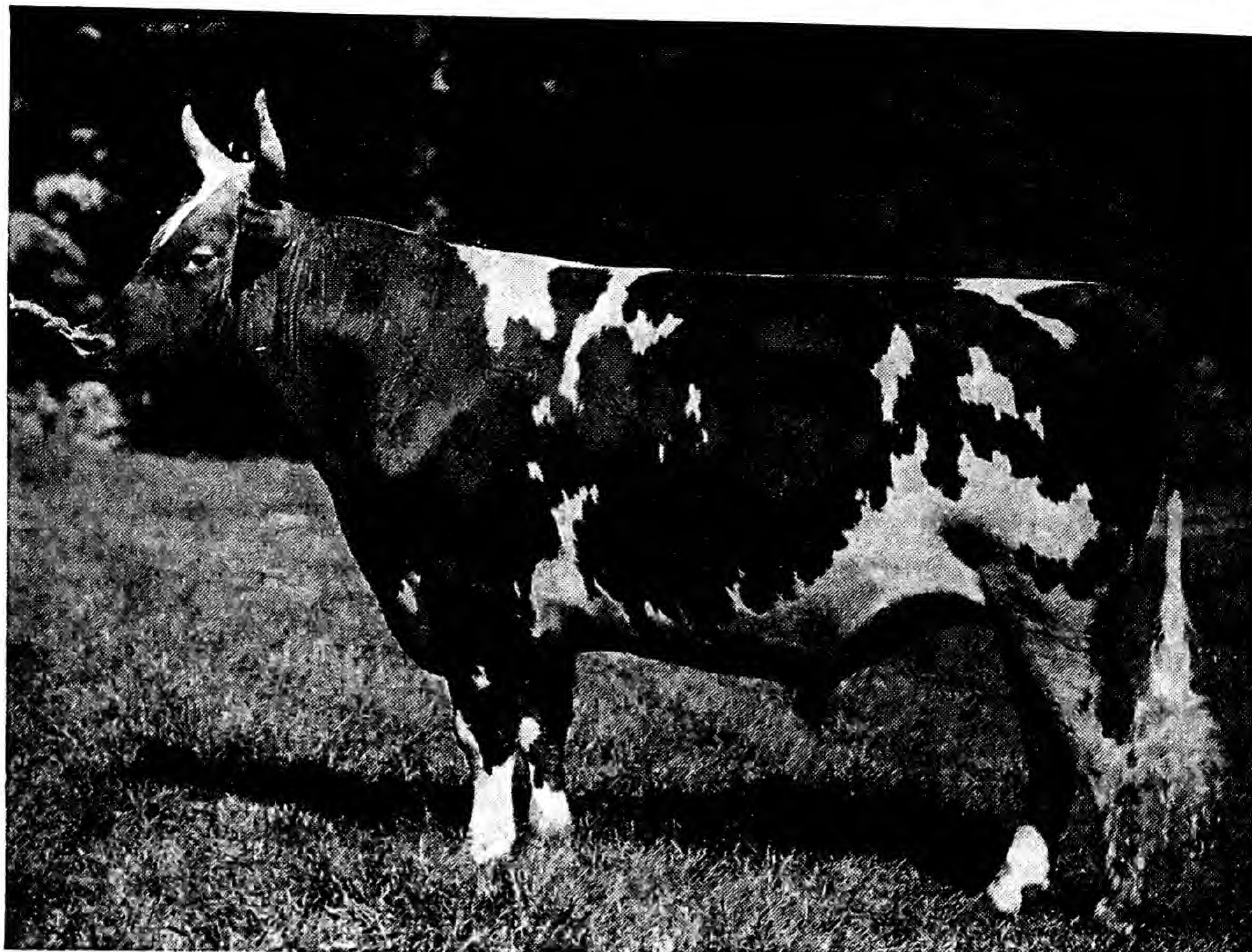
The Ayrshire is noted for its long, especially curved horns that added materially to the appearance of the animal. The typical horns must possess the right curves, usually attained through special training by use of appropriate apparatus. In dairy conformation the Ayrshire varies from individuals of extreme refinement to others that are quite beefy. The average Ayrshire is more thickly fleshed than either the Jersey or the Guernsey. (Figs. 29 and 30.)

Color. The typical Ayrshire is red with white spotting. The red varies from light red through brown to a color almost black which is usually referred to as mahogany. The darker color usually predominates about the head and forequarters, fading into lighter shades toward the rear, although some animals may be of uniform dark color throughout. The black is dominant in the male and the lighter red is dominant in the female; this accounts for a much larger proportion of mahogany colored males than females.

The extent of white varies greatly. Some individuals are almost entirely white, while others are almost entirely pigmented. The predominating red color is preferred by most breeders.

Disposition. The Ayrshire is more active than any other breed. The cows are quite nervous and are sometimes hard to manage. On account of their nervous disposition and well-developed horns, considerable damage may be done to members of the herd from horn injuries. The bulls are frequently vicious. These cattle are unexcelled as grazers. Their unusual stamina and activity enables them to obtain adequate nutrients from pastures where some other breeds would starve.

Maturity and longevity. The Ayrshire is somewhat slower in maturing than the Guernsey and earlier than the Holstein. Under normal conditions Ayrshire heifers are sufficiently developed to come into milk when 26 to 28 months of age. Maximum weight and production are attained at from six to seven years of age. Claims are made, although adequate figures to sustain them are not available, that the Ayrshire is the longest lived of any



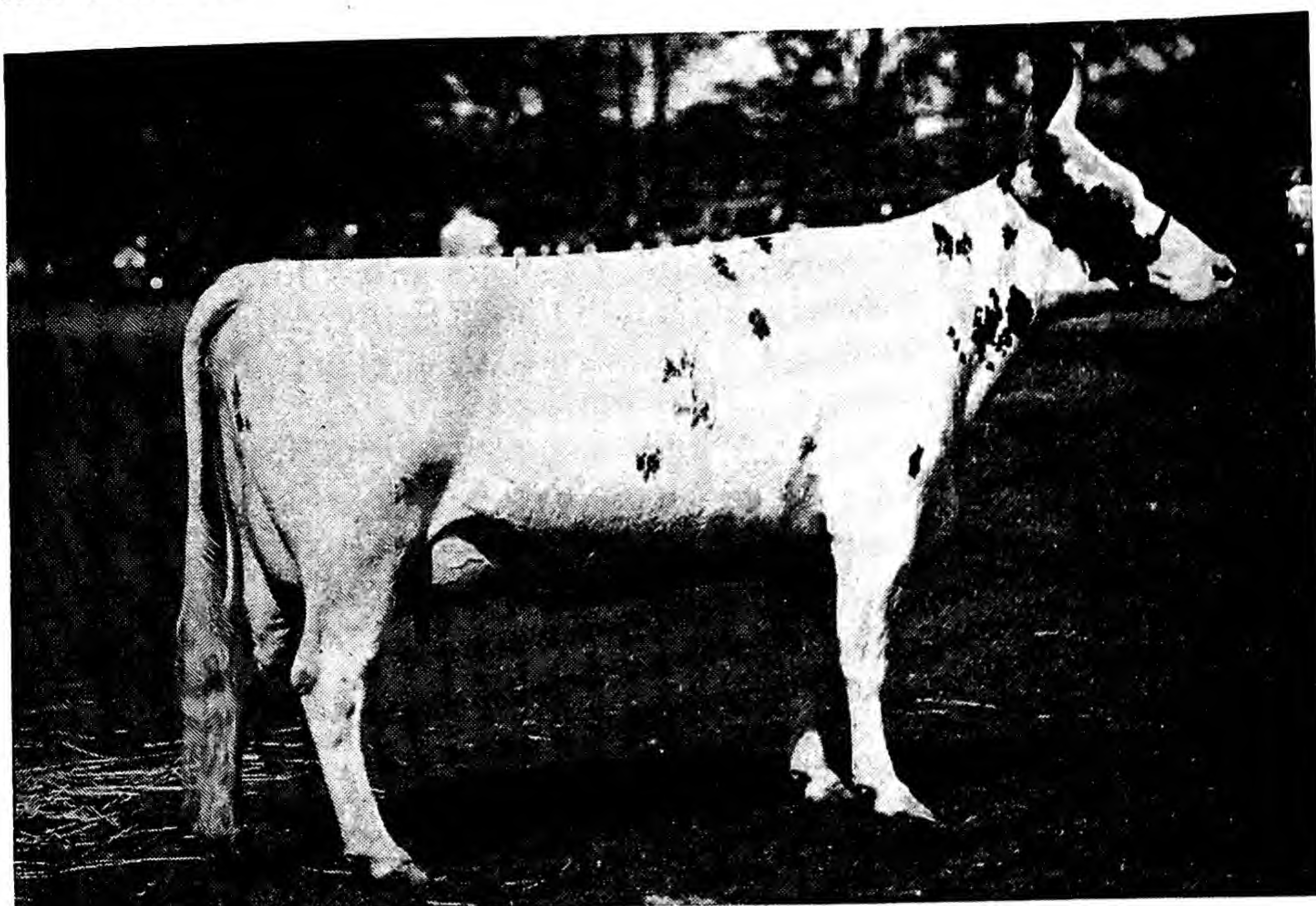
Ayrshire Breeders' Association

Fig. 30. Cowgrove Golden Sun, a noted show ring winner, represents excellent Ayrshire type.

of the breeds. There are as many cows producing and reproducing at 20 or more years of age as are found in any breed, if not more.

Reproduction, veal, and meat. As a reproducer the Ayrshire ranks high. The calves weigh from 70 to 80 pounds at birth and are strong, vigorous, and easy to raise. Ayrshire calves make veal of high quality; but due to a smaller birth weight they are not so desirable for this purpose as are the Holstein and Brown Swiss calves. The Ayrshire ranks high among the dairy breeds for beef. Dry cows, as well as steers and heifers, fatten readily. The fat of the Ayrshire does not possess the high yellow color of the fat that detracts from the beef value of the Jersey and the Guernsey.

Milk. Judging from the leading records of the breed, the Ayrshire does not reach the high production of either butterfat or milk that some other breeds do. A number of Ayrshires lack somewhat in persistency, although some are excellent in this respect. The milk of the Ayrshire, on an average, contains 4.0 per cent fat, 3.34 per cent protein, and 12.72 per cent total solids. The milk is especially well adapted for market milk and cheese making. Because the fat particles are the smallest found in milk of any breed, claims are made of the superiority of Ayrshire milk for infant and invalid feeding. Claims are also made that the curd of Ayrshire milk is softer than that of milk from other breeds.



Ayrshire Breeders' Association

Fig. 31. Alfalfa Farm Ann 2nd, an Ayrshire cow of excellent type. She was grand champion cow as well as winner of the milking contest of the Eastern States Exposition in 1937, and also Grand Champion at the 1937 National Dairy Show.

Home and origin. The Ayrshire is the youngest of the dairy breeds. The chief development of the breed took place following 1750, when the other dairy breeds were well established. The Ayrshires were developed in the County of Ayr (Ayrshire), located in southwestern Scotland. There is nothing definitely known about the stock from which the Ayrshire was developed, but it is generally supposed that cattle from Holland (Holstein), the Channel Islands (Guernseys and Jerseys), and Teeswater cattle were used to produce the Ayrshire. The Ayrshire, therefore, has its origin in both the *longifrons* and the *primigenius* types.

The climate of Ayr is not favorable to livestock raising because it is cold and damp a great part of the year. In the early development of the breed the forage was scant, as the soil of this part of Scotland is not fertile. The extreme hardiness and rustling ability of the animal undoubtedly is attributable to the character of the country in which she was developed, as only those individuals with unusual ruggedness could have survived to reproduce their kind. Originally the Ayrshires went by the name of Dunlap; later they were known as the Cunningham breed; and not until 1803 were they generally known as Ayrshire.

Importation and distribution. The first importation of Ayrshires was made in 1822. None of these was kept pure. The first Scotch settlers of Canada brought cattle from Ayr with them; but like the first importation

into the United States, they were not kept pure. From 1830 to 1860 there were frequent importations of Ayrshires into the United States. Commencing about 1860, Ayrshire importations declined in favor of importations of Holsteins and the Channel Island breeds. Importations are still made from Scotland and Canada.

In the United States Ayrshires are most numerous in New York, the New England states, Pennsylvania, and Ohio. The Ayrshire is the leading dairy breed in Scotland and is numerous in Finland, England, New Zealand, Australia, and eastern Canada.

From 1929 to 1947, 38,968 Ayrshires were imported from Canada. Of these, only 31.3 per cent were registered in the herd books of the Ayrshire Breeders Association even though all importations were purebreds. Since purebreds come in free while commercial cattle are subject to importation duty, it is obvious that most of these cattle were purchased for commercial dairy purposes. In 1947, the total importations from Canada was 3,762 head, of which 1,864 were registered.

Registration. All records are kept by the American Ayrshire Breeders Association, with offices in Brandon, Vermont. This association was organized in 1875. The American Ayrshire Breeders Association, like the other dairy breed organizations, not only keeps the Herd Book records, but also has supervision of the Advanced Registry and engages in promotional work for the breed. To date, the Ayrshire Association has not employed field men for promotional work but has relied upon literature for this purpose. A total of 91,185 males and 361,521 females have been registered by the Association up to 1948. During the depression years, Ayrshire registration held up very well. In 1934, 17,436 males and females were registered; this was the highest number to be registered in one year up to that time.

The increase in annual registrations has been great. In 1947, a total of 30,046 animals were registered by an estimated 10,000 breeders. In 1947, approximately 4,000 breeders were members of the Ayrshire Breeders Association.

Special provisions are made for the registration of polled Ayrshires, by which the symbol X precedes the registration number. In 1947, 103 polled Ayrshires brought the total up to 427.

Testing. The Ayrshire Breeders Association adopted an Advanced Register system in 1902. At that time and for many years thereafter the regulations permitted of four time daily milking and provisions were made for 305- and 365-day records with or without calving requirements. Minimum requirements in milk and butterfat were set up for each of the customary age groups for qualifications for entry in the Advanced Register. With the adoption of the Herd Test plan in 1925, the emphasis was shifted from Advanced Registry until today all testing of Ayrshires is virtually on the Ayrshire Herd Test plan. This breed was the first to adopt such a test plan.

Under the Herd Test, all cows in the herd must be entered on test. Certificates are issued for the herd and each individual cow regardless of

the production level. No record of production exceeds 305 days that must be consecutive but may include portions of two lactation periods.

Meritorious certificates for individual cows. Meritorious Certificates are issued for individuals that drop living calves within 14 months from their previous freshening and that on twice daily milking equivalent, produce not less than the following milk and butterfat in 305 consecutive days with average butterfat test of at least 3.9 per cent. The 305 days may be in one or in portions of two lactations.

Age	Milk	Fat
	Pounds	*Pounds*
Mature	10,000	400
Sr. 4	9,400	376
Jr. 4	8,800	352
Sr. 3	8,200	328
Jr. 3	7,600	304
Sr. 2	7,000	280
Jr. 2	6,400	256

Bulls are admitted to the Advanced Registry when four daughters from four different dams have qualified for entry. Meritorious Herd Tests are accepted on the same basis as the Advanced Register records in qualifying a bull for Advanced Registry.

A total of 66,554 production records have been made that average 9,016 pounds milk and 367.8 pounds butterfat with an average of 4.08 per cent butterfat. In 1947, 12,054 cows were on test which represents a larger proportion of Ayrshires on test than any other breed.

Garclough May Mischief holds the American record for high milk production with 25,329 pounds of milk and 894.9 pounds of fat. The butterfat record is held by Lily of Willowmoor with 955.6 pounds of fat and 22,596 pounds of milk.

The highest producing Ayrshire in Scotland is Nether Craig Janet, who has a record of 30,910 pounds of milk and 1,171.4 pounds of fat.

Approved sire. This is a term applied to Ayrshire bulls that have ten or more tested daughters out of tested dams that meet the following requirements:

1. The average of all tested daughters shall be not less than 9,000 pounds milk and 360 pounds fat with a test of not less than 3.9 per cent.
2. The equal parent index of an Approved Sire shall be not less than 8,500 pounds milk and 340 pounds fat with a test of at least 3.9 per cent.
3. At least 60 per cent of the tested daughters shall each have 9,000 or more pounds milk or 360 pounds fat.
4. At least 50 per cent of all registered three year old daughters must be tested. All such daughters in a herd that is on test must be included.

Provisions are made for approving bulls that have daughters in herds not testing in which event 15 daughters will be used as a minimum. All records are computed to mature equivalent twice daily milking basis of

not more than 305 days and the first lactation records shall be used except by breeder request when averages of all records of each tested daughter are used in the computation.

Herd Test, Advanced Registry, and Roll of Honor records shall be used. Dairy Herd Improvement Association records may also be used provided the record books are sent in to the Ayrshire Breeders Association for checking and approval.

Approved dams. To qualify as an Approved Dam an Ayrshire cow must have three or more daughters that are tested and all such meet the following requirements:

1. The average shall be not less than 9,000 pounds milk and 360 pounds fat with at least 3.9 per cent test or at least 10,000 pounds milk and 400 pounds fat if testing less than 3.9 per cent.
2. Not less than 60 per cent of all tested daughters must each produce not less than 8,500 pounds milk and 340 pounds fat.

The types of records used and the method of computation of these records are similar to those specified under Approved Sires. Once either a cow or a bull has become Approved they will retain such designation even though subsequent tested progeny may reduce the requirements below that required for qualification.

Type classification: In 1942, Type Classification was adopted for cows and in 1947, the system was opened for bulls. A total of 16,297 cows and 312 bulls had been classified to the end of 1947. The breakdown of the numbers and per cent for the various classes are as follows:

Class	Number	Per Cent
Excellent	645	4.0
Very Good	4,588	28.2
Good Plus	6,943	42.6
Good	3,546	21.8
Fair	557	3.4
Total	16,297	100.0

Selective registration of bulls. In 1945, the Ayrshire Breeders Association adopted a plan for selective registration of bull calves in which bulls are grouped into three classes: (1) Standard, (2) Selected, and (3) Preferred pedigrees. The objective of this program is to encourage matings which have a better chance of improving production.

Standard pedigree. Any bull whose parents are registered will be registered upon proper application. Such a registration is classed as Standard.

Selected pedigree. A bull upon registration will be given a Selected pedigree when none of the six nearest ancestors (parents and grandparents) show any evidence of low production and where at least satisfactory production is evidenced for at least one parent or two grandparents or satisfactory progeny performance for at least one parent or two grandparents. At least 8,500 pounds milk and 340 pounds butterfat

in 305 days on two times daily milking as a mature equivalent is required for a satisfactory rating. Females in the pedigree will be rated satisfactory for the Selected pedigree with this or greater production. Bulls must have five or more daughters that average at least this amount of milk and butterfat. All individuals in the first two generations must meet the minimum set forth above if tested.

Preferred pedigree. To qualify for the preferred pedigree rating one of four combinations of approved breeding must be met. These four combinations are, (1) Approved Sire and Approved Dam, (2) Approved Sire and Approved Maternal Grand Sire and the dam having produced at least 9,000 pounds milk and 360 pounds butterfat in 305 days on twice daily milking and mature equivalent basis, (3) Approved Sire and the dam producing not less than 9,000 pounds milk and 360 pounds butterfat in 305 days on twice daily milking and mature equivalent basis, and (4) Approved Dam and sire with at least 5 daughters averaging not less than 9,000 pounds milk and 360 pounds butterfat in 305 days on twice daily milking and mature equivalent basis.

Chapter 15

THE BROWN SWISS

CHARACTERISTICS. THE BROWN SWISS IS THE LARGEST AND MOST RUGGED of the dairy breeds. Cows under normal conditions weigh 1,300 to 1,400 pounds, and bulls weigh 1,800 to 2,500 pounds. Originally the Brown Swiss was regarded as a triple-purpose cow and is still used as such; in her native home, in addition to producing milk, she is used as a beast of burden and is the source of practically all meat used. In America the Brown Swiss is strictly a dairy breed. The head is large and somewhat dished. The bones are heavy and the skin is thick and loose, usually forming heavy folds about the throat and brisket. On an average the Brown Swiss is rougher than the other dairy breeds. However, no breed has made as rapid improvement as the Brown Swiss. Animals shown at the leading shows are as good a type as any other breed. The udders are usually well formed and well attached. (Figs. 32 and 33.)

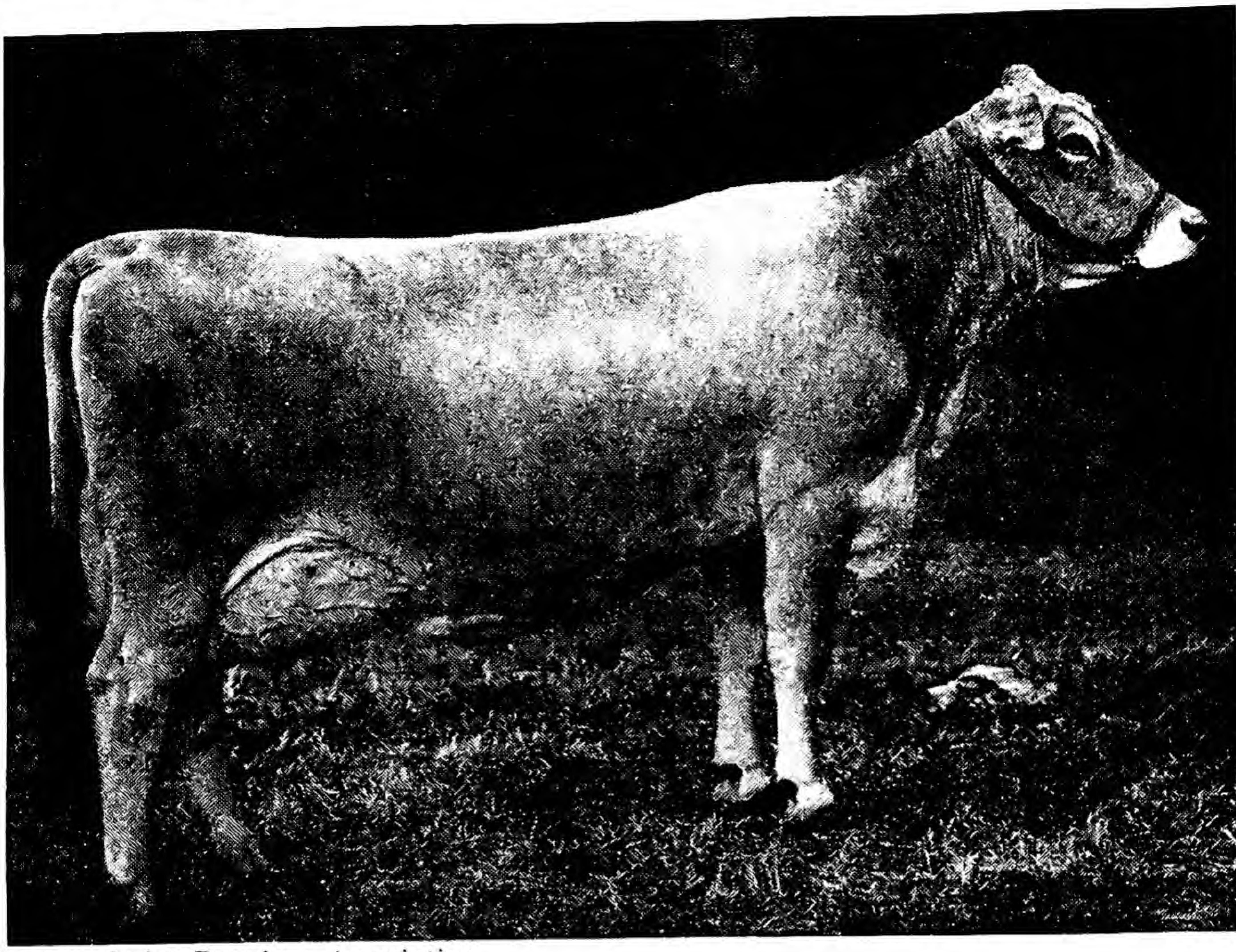
Color. The color varies from a light fawn to an almost black, with a mouse color predominating. The muzzle is encircled by a mealy shaded band and the lips are light in color. Along the backbone is a stripe of lighter color which gradually blends with the darker colors of the side. The nose, tongue, switch, and horn tips are always black. White is absent except on the inguinal region and on the udder. The calves are light in color when born and become darker as they grow older.

Disposition. The Brown Swiss are docile and not easily excited. They are easy to manage in the everyday routine about the dairy. Frequently, however, Brown Swiss are stubborn and refuse to respond when attempts are made to alter the regular routine, such as changing them to another stall or training them for showing. When once they learn that such things are expected of them, they comply and become co-operative.

While the Brown Swiss are phlegmatic, they are excellent rustlers. In spite of their large size and consequently great nutrient requirements they do well on ordinary pasture. Their general ruggedness enables them to withstand adverse conditions, such as rough treatment and cold, better than members of other dairy breeds.

Maturity and longevity. The Brown Swiss is the slowest of the dairy breeds to mature. Normally, heifers are not sufficiently developed to come into milk until they are 30 to 36 months of age. Cows are not considered mature for official test purposes until they are six years of age, while for all other breeds cows are considered mature for this purpose when they are five years of age.

To compensate for the lateness in maturing, the Brown Swiss live and produce and reproduce longer than individuals of other breeds. Brown Swiss authorities claim a higher proportion of old cows for their breed



Brown Swiss Breeders Association

Fig. 32. An excellent Brown Swiss cow, Jane of Vernon 29496, Grand Champion at the 1936 National Dairy Show. She is the highest producing four year old of the breed, with 23,569 pounds of milk and 1,075.6 pounds of fat.

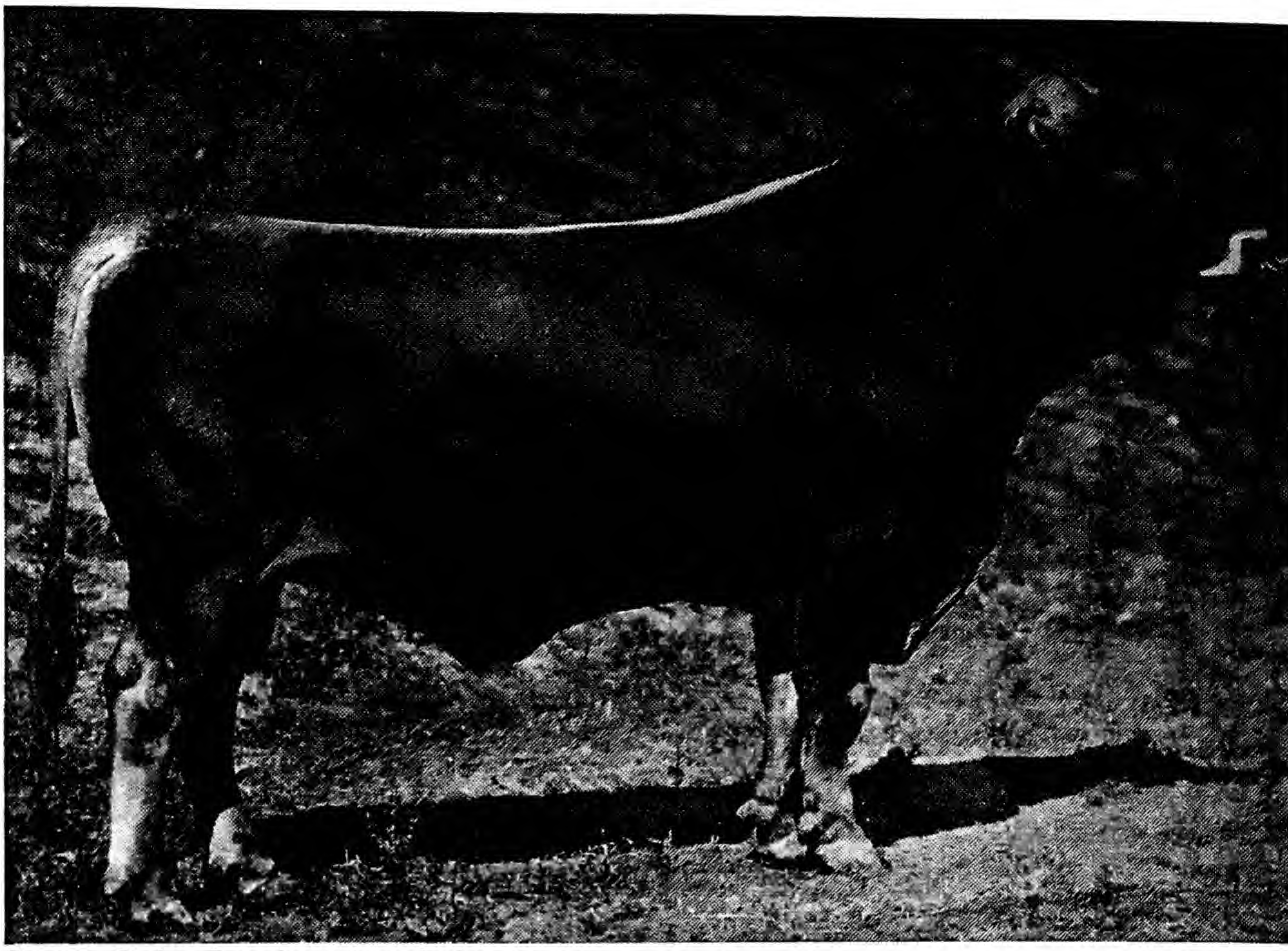
than is found in other dairy breeds. A 13 year old Brown Swiss cow has produced over 1,000 pounds of butterfat in 365 days.

Reproduction. The Brown Swiss rank high as reproducers. Relatively little sterility is reported for the breed. The calves are large, strong, and rugged when born and are easy to raise. The average birth weight of the calves ranges from 90 to 95 pounds. It is not uncommon for Brown Swiss calves to weigh as much as 120 pounds at birth.

Meat and veal. Because of the large birth weight and white fat, Brown Swiss calves rank among the best for veal production. Among the dairy breeds the Brown Swiss cattle also rank high for beef production. When they are not milking, they fatten readily to produce beef of fair quality.

Milk. The milk from the Brown Swiss is adapted to a variety of uses. It contains, on the average, 4 per cent fat; this makes it particularly well adapted for market milk, cheese production, and condensed milk, as well as for butter making. The milk is described as white. The fat particles are small and low in yellow coloring matter.

Home and origin. The Brown Swiss is probably the oldest of dairy cattle breeds. They are descendants of *Bos longifrons*, and were developed in the mountain territory in the northeastern part of Switzerland in the



Brown Swiss Breeders Association

Fig. 33. An excellent Brown Swiss bull, March Molly 3rd's Master 1435 D.

Cantons of Zurich, St. Galen, Lucerne, and Schwyz. From the literature it is apparent that the cattle of Switzerland at the time of Caesar answered the description of the present Brown Swiss. The bones found in the ruins of the Swiss Lake dwellers date back to probably 4000 B.C. and resemble closely the skeleton of the modern Brown Swiss.

Conditions in Switzerland. The home of the Brown Swiss is the most rugged country in which agriculture is practiced. The cattle are usually pastured on the mountain slopes, beginning at the foot in the spring and going up the mountainside as the snow recedes. In the fall they are brought down the mountainside and housed in barns located in the valleys. Their feed during the spring and summer months is limited entirely to the grasses on the mountain slopes. In the winter time, they are fed mainly on meadow hay grown in the valleys. Occasionally roots and oil cake are added to the winter's ration.

Today, as for many centuries past, the Swiss are famous for their cheese production; these cheeses are made from the milk produced by the cattle pastured on the mountain slopes. Since only hardy animals, able to withstand frequent exposure to storms and to endure the ruggedness of the country in which they have been developed, could have survived to reproduce, it is easy to understand that the Brown Swiss have the strongest constitution of any of the dairy breeds.

Importation and distribution. A total of 25 bulls and 160 females has been imported into the United States. The first importation was made in

1869 by H. M. Clark of Massachusetts, and the most recent importation was made in 1931 when four bulls and one heifer were imported. From 1916 to 1931 no importations were made because of the difficulty of getting animals out of Switzerland without going through territory infected with foot and mouth disease.

From the 185 imported animals over 100,000 Brown Swiss have been recorded. Brown Swiss are found in all the states, but they are most numerous in Wisconsin, Illinois, New York, and Michigan. The breed has never experienced a boom, but it has enjoyed a steady growth in which the demand for cattle has exceeded the supply. As a result, the prices paid for Brown Swiss declined but little during the depression years. The Brown Swiss has also experienced a greater percentage increase in registered stock than any other breed.

Record keeping. All records pertaining to the breed are kept by the Brown Swiss Breeders Association, with headquarters at Beloit, Wisconsin. The organization was formed in 1880, but it did not publish the first Herd Book until 1908. It is the youngest of the major dairy breed associations. The Brown Swiss Association sponsors the monthly publication, *The Brown Swiss Bulletin*, for the breed. It has also published promotional literature and assisted with prize money at fairs. In 1948 there were about 2,400 members of the Association and about 10,000 active breeders of Brown Swiss cattle. A total of 185,415 females and 89,880 males had been registered to July, 1948. In 1947 alone, 22,469 animals were registered.

Advanced Registry. In 1911 the Brown Swiss Breeders Association adopted a system of Advanced Registry known as the Register of Production. In 1932 a Herd Improvement Test, a test similar to the herd test plans of the other breed associations, was adopted.

Four classes of records are recognized by the Register of Production. These are the yearly test, the ten months' (305 days) test, the 365 day farmers' class, and the 305 day farmers' class. In order to qualify for entry in the Register of Production in the 365 day test, the individual must produce at least 250.5 pounds of fat when 30 months of age (the youngest age provided for) and an additional .1 pound of fat for each day older than 30 months up to five years and six months, when the requirement is 360 pounds of fat. To qualify for entry in the 10 months' division, a minimum butterfat production is required which is 30 pounds less than the requirements for the corresponding ages in the 365 day test. In addition, a living calf must be dropped within 14 months from the date of the last calving.

The requirements for entry into the Farmers' division, 365 and 305 day tests, are the same respectively as those listed in the preceding paragraph. For the Farmers' class, cows may not be milked more than twice daily except for the first 15 days, when they may be milked three times daily. For the other Register of Production Classes the limitations as to the number of milkings daily is four.

Up to October 1947, there were a total of 1,815 Register of Production records of all classes. In recent years Herd Improvement Records have

been stressed resulting in a great increase in the numbers tested on this plan.

The following tables present the numbers tested in each age class with the average milk, fat and fat percentage for 2 X milkings.

HERD IMPROVEMENT RECORDS PRODUCTION AVERAGES
305-DAY 2 X LACTATION RECORDS

Number Cows	Pounds Milk	Ave. Per Cent	Pounds Fat
Mature 3,538	10,331.5	3.91	404.47
5 Year 1,347	9,878.3	3.99	394.31
Sr. 4 Year 605	9,691.6	4.00	387.46
Jr. 4 Year 1,042	9,314.2	3.89	362.56
Sr. 3 Year 1,105	9,022.2	4.01	361.69
Jr. 3 Year 901	8,630.0	3.80	327.85
Sr. 2 Year 1,079	7,867.8	4.06	319.33
Jr. 2 Year 1,291	7,526.0	4.06	305.91
12 Years and Over 263	9,446.3	3.87	365.43

HERD IMPROVEMENT RECORDS PRODUCTION AVERAGES
305-DAY 3 X LACTATION RECORDS

Number Cows	Pounds Milk	Average Per Cent	Pounds Fat
Mature 285	13,137.1	4.00	524.83
5 Year 102	12,808.1	3.93	503.32
Sr. 4 Year 69	12,462.2	4.01	499.92
Jr. 4 Year 71	11,846.9	4.00	473.87
Sr. 3 Year 68	11,820.0	4.01	474.36
Jr. 3 Year 63	11,037.7	3.97	438.50
Sr. 2 Year 71	9,574.1	4.15	397.65
Jr. 2 Year 71	9,086.0	3.95	359.30
12 Years and Over 11	11,778.2	3.82	449.51

A total of 18 cows have completed yearly records above 1,000 pounds butterfat, the ten high of which follows:

BROWN SWISS COWS HAVING PRODUCED 1,000 POUNDS BUTTERFAT

Name of Cow	Age	Pounds Milk	Pounds Fat
Illini Nellie 26578	8–4–2	29,569.5	1,200.41
Mary's Nell 36395	6–11–17	29,487.2	1,109.71
Swiss Valley Girl 10th 7887	12–4–15	27,513.6	1,106.33
Jane of Vernon 29496	4–7–18	23,569.0	1,075.58
Illini Nellie 26578	9–10–5	27,897.6	1,062.80
June's College Girl 11427	5–11–25	24,571.6	1,062.30
Royal's Dominie of Lee's Hill 66540	7–7–4	24,978.4	1,056.54
Royal's Dominie of Lee's Hill 66540	9–2–7	25,437.2	1,047.93
June's College Girl 11427	10–7–12	24,167.4	1,043.02
Jane of Vernon 29496	10–11–12	21,880.2	1,039.08

A total of 63 cows have produced more than 4,000 pounds of fat in a lifetime up to 1948. Twenty of this group were added during the fiscal year ending September 30, 1947. The highest lifetime record is held by Swiss Betty I, 19935, with 171,336.4 pounds milk and 7,464.59 pounds butterfat in 4,140 days.

Type classification. In 1942 the Brown Swiss Cattle Breeders Association, adopted a type classification program. Since that time up to the end of the fiscal year 1946–1947, a total of 8,674 cows were classified. Bulls are not classified, and cows that have received ratings of Excellent and Very Good are reclassified on reclassification of the herd. In rating Brown Swiss cows, the classifying judge must ascribe a classification value to each of the following: general appearance, with subratings for: legs and feet, rump, dairy character, and body capacity; and mammary system, with subratings for fore udder and rear udder.

The percentage distribution of the 8,674 cows classified for each of the six classes is given in the following table:

Class	Classification Rating	General Appearance	Mammary System
Excellent ...	1.2	1.8	1.7
Very Good ..	22.9	24.5	18.5
Good Plus ..	47.9	38.8	46.1
Good.......	25.4	23.4	29.1
Fair........	2.7	1.7	4.5
Poor	.0	.0	.6

The Brown Swiss Cattle Breeders Association have adopted the standard score card.

Chapter 16

THE MILKING SHORTHORN

CHARACTERISTICS. THE MILKING SHORTHORN RANKS WITH THE HOLstein and the Brown Swiss in size. Normal mature cows weigh from 1,400 to 1,600 pounds, with individuals weighing over a ton. Bulls weigh 2,200 pounds and upward. Either polled or horned Shorthorns may be Milking Shorthorns. Up to 1935 no distinction was made in registration between milking and beef types. Beginning in 1935, the breeder who wishes to have his cattle recognized as Milking Shorthorns declares them to be of the milking type, and the registry certificate issued bears the words "MILKING SHORTHORN" on the face.

The Milking Shorthorn may be white, red and white, red, or roan in color. The red varies from a moderately light shade to a fairly dark shade. When individuals are red and white, the red usually predominates, and the legs are red.

Type. There is no sharp line of demarcation between the beef Shorthorn and the dairy Shorthorn. Much variation is found in the type of the Milking Shorthorn, from extreme beef to extreme dairy types. Many of the highest producing Shorthorns resemble the Holstein except for color. The standards for the breed, however, call for a true dual-purpose individual. (Figs. 33 and 34.)

Dairy characteristics. For reasons just mentioned, the Milking Shorthorn is the most variable of the breeds for milk and butterfat production. Many breeders have developed herds with extreme dairy conformation and high production. Others change the designation from dairy to beef and vice versa periodically, depending upon market conditions; these breeders frequently alternate in using bulls of the milking and beef types. While the Milking Shorthorn people aim to breed cows that are intermediate between beef and dairy types, they point with pride to the fact that an Australian Shorthorn cow, Melba 15th of Darbalara, for many years held the world's record over all breeds for butterfat production, with 1,614.1 pounds. The avowed aim of the breeders of Milking Shorthorns is to breed cows that will produce 8,000 to 10,000 pounds of milk testing 4 per cent fat annually when the cows are mature. Under average farm conditions 6,000 pounds of milk and 240 pounds of fat would be considered good.

The milk resembles that of the Ayrshire. The fat content averages 4 per cent; the fat particles are small; and the color is rather low. The milk is particularly adapted for market milk, condensed milk, and cheese production.

Because there is a great variation in the inheritance of beef and dairy tendencies the breeders of Milking Shorthorns have a difficult problem in maintaining the dual-purpose type. The tendencies are for individuals to

Bruington Brothers

Fig. 34. Brookside Satin 11th, Grand Champion Milking Shorthorn female of 1934, has a record of 11,193.0 pounds of milk and 408.7 pounds of fat.

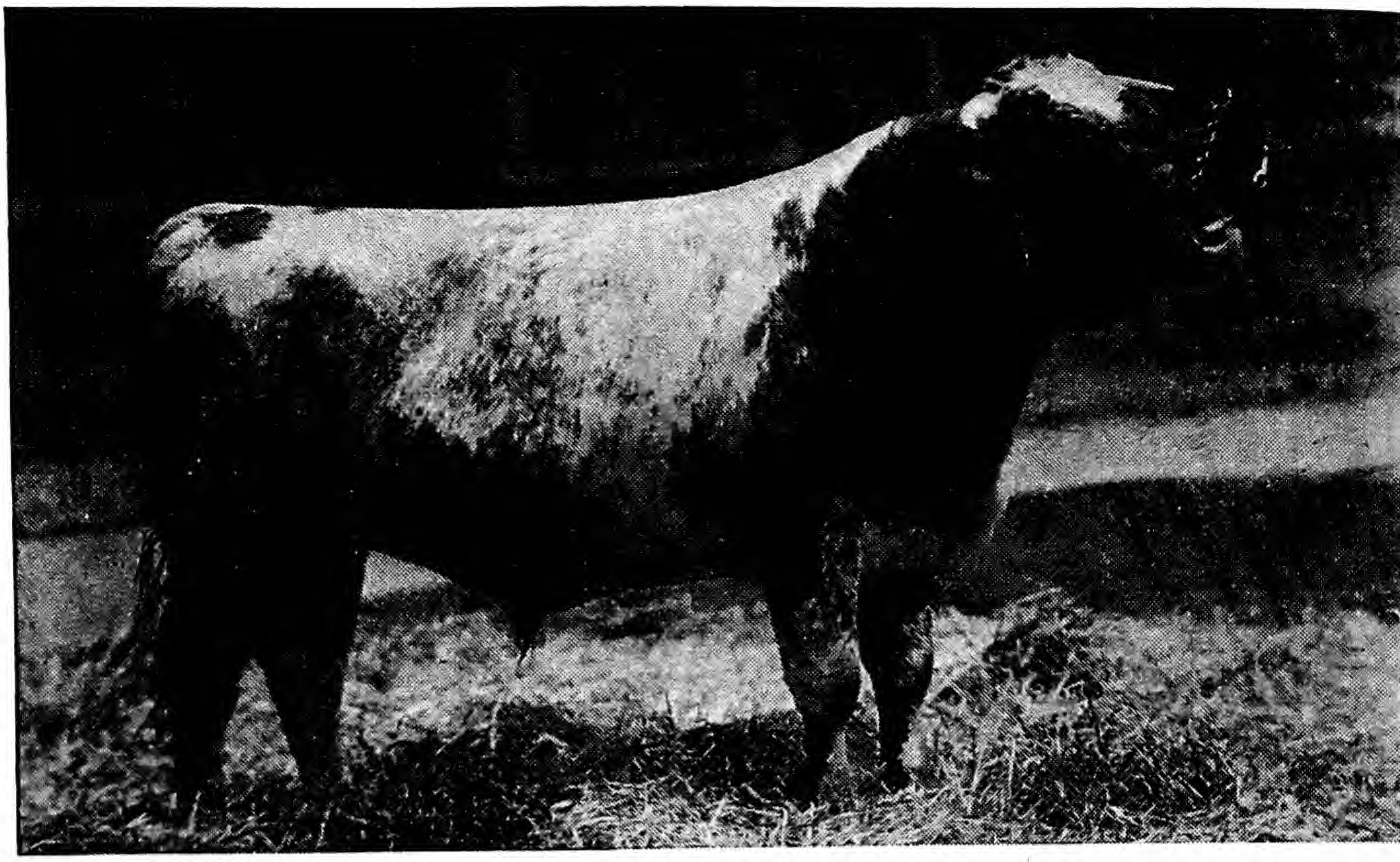
revert either to strictly beef or to extreme dairy types. Milking Shorthorns are not so persistent as the more highly specialized dairy breeds.

Beef characteristics. The Milking Shorthorn cows excel all other milking breeds for beef. They usually lose flesh when in full milk, but they fatten rapidly when dry. The steers grow rapidly and make beef of the highest quality.

Calves and reproduction. The weight of the calves at birth normally varies from 75 to 80 pounds. This is about 6 per cent of the mature weight, or the smallest value for any breed. Because the birth weight of the Shorthorn calves is small, they are not so well adapted for veal production as the Holstein or the Brown Swiss calves. The Shorthorn ranks only average as reproducers. The calves, however, are vigorous and quite easily raised. In maturity they rank with the Holsteins. Heifers of normal growth and development come into milk at 28 to 30 months of age.

Adaptation. The Shorthorn is particularly well adapted to large farms where both milk and beef production is desired. On such farms a number of the superior milk producers may be selected for milking and the rest used for strictly beef production. By careful selection and use of the proper bulls, a high producing herd may be established under such conditions.

Origin and development. As for some of the other breeds, the origin of the Shorthorn is obscure. Its native home is in northeastern England in the Counties of Durham, Northumberland, and York. In the past they were also known as Durhams. It is generally believed that the early invaders of England, particularly the Romans and the Normans, brought cattle from



Borg Farm

Fig. 35. An excellent type Milking Shorthorn bull, Northwood Gift 13th.

the Continent, and that these cattle had a large part in the development of the Shorthorn. Later Flemish cattle were brought over from Holland and crossed with the native cattle, and possibly other cattle were also used.

At the beginning of the eighteenth century the cattle from which the Shorthorns have been developed were mediocre and lacked uniformity. It was through the efforts of great breeders that the superior breed of cattle now known as the Shorthorn was developed. The accomplishments of the breeders who developed the Shorthorn breed are classic; and as a result the names and work of Charles and Robert Colling, Amos Cruickshank, Thomas Booth and his sons John and Richard, and Thomas Bates have become historic in the livestock field. Of these the work of Thomas Bates is of particular interest to those interested in dairying.

Thomas Bates selected and bred for high milk production, while the rest of the great breeders selected mainly for superior beef qualities. Although not all the Milking Shorthorns trace back to the breeding of Bates, most of them do, and the principles he followed in establishing a high producing strain of Shorthorns are still sound and practiced by the best breeders. Bates began his breeding operations about 1790, or about ten years after the beginning of Shorthorn improvement, which was started with the work of the Colling brothers.

Bates selected and bred Shorthorns for a combination of dairy and beef qualities. Only those animals that met with his standard were selected for breeding purposes, and inbreeding was extensively practiced. He developed about six families, of which the Duchess family was the most noted. As a result of the intensive inbreeding, considerable loss in fertility was experienced. After the death of Bates in 1849, the herd was dispersed,

and no great breeder carried on the program developed by him. His results, however, were so outstanding and the influence so great that most of the Milking Shorthorns of today trace back to his cattle.

Importation and distribution. The first Shorthorns were brought to America in 1783 by Gough and Miller of Virginia. The first pedigreed Shorthorns were imported in 1817 by S. M. Hopkins of New York. Since that time thousands of Shorthorns have been imported. Until recently no distinction was made between dairy and beef types, and therefore there is no way of knowing what proportion of the importations were Milking Shorthorns.

In England the Milking Shorthorn is a major dairy breed. In the United States the majority of Shorthorns are of the beef type. Not until 1935 was any attempt made to ascertain the relative numbers of dairy and beef Shorthorns. Since then about 30 per cent of all Shorthorns registered have been designated Milking Shorthorn. A total of 25,072 such animals were registered from April 1, 1935, to August 20, 1937. Milking Shorthorns are most numerous in Minnesota, Iowa, Illinois, Wisconsin, Kansas, and Michigan.

Breed organization. The records of the Milking Shorthorns up to 1948 were kept by the American Shorthorn Breeders' Association, with headquarters at Chicago. The Milking Shorthorns were registered in the same herd book as the beef types. The Milking Shorthorn breeders are represented upon the board of directors of the American Shorthorn Breeders' Association in proportion to the number of milking type cattle registered. In 1948, the Milking Shorthorn people set up their own herd books and formed a society known as the American Milking Shorthorn Association, with offices in Chicago. All animals registered as Milking Shorthorns in the American Shorthorn Herd Books and their offspring are eligible to be registered in the new Herd Book.

Advanced Registry. In 1912 an Advanced Registry system was adopted by the American Milking Shorthorn Club. This is known as the Record of Merit; and in order to be eligible for admittance thereto, a cow must produce 5,250 pounds of milk and 210 pounds of fat in 365 days at the age of 30 months. The requirement increases until the cow is five years of age, when she must produce 8,000 pounds of milk and 300 pounds of fat.

If a living calf is produced within 14 months from the previous calving, entrance to the Record of Merit may be attained from a production of 90 per cent of the 365 day requirements in 305 days. This is also known as the double letter record.

Four classes of records are accepted, each of which is designated by a letter. Class A records are supervised by the State Agricultural College and are also known as official tests. Class B are supervised by the tester of a cow testing association and are known as semiofficial tests. Class C are privately kept records. All three of these classes of records require that daily milk weights be kept by the owner and forwarded monthly to the association. A fourth class, CT, also known as the Dairy Herd Improvement Association Records, does not require daily milk records, but a

monthly report of the testers' findings is necessary. (See the following table.)

Ten Highest Milking Shorthorn Fat Records

Name	Pounds of Milk	Pounds of Fat	Class
Ruth B 568209	21,641.0	956.70	B
Mountain Princess 1635668	21,023.2	853.51	A
White Molly 1415398	18,346.3	806.88	A
Lady Ury 1506672	17,723.0	800.48	C
Bonvue Rose Meade 1284449	20,429.9	785.55	A
Trixie 3d 1329412	16,119.8	770.21	B
Allington Kirklevington 1542774	20,543.1	754.78	A
Trixie 3d 1329412	16,543.6	745.93	B
Queenston Belle 764413	15,203.4	744.90	C
Glenside Pearl Clay 921066	18,005.6	719.61	B

Up to June 1947 a total of 17,205 cows have both milk and fat records averaging 324.7 pounds of fat, and 7,835 cows have milk records averaging 8,188 pounds of milk.

Grading up plan. The Milking Shorthorn Society has adopted a plan making it possible by successive use of purebred sires to develop animals that are eligible for registry. This plan is similar to plans adopted by most British breed societies. The stages of improvement and registry are as follows:

Class A—Foundation cows that have freshened once or more, duly inspected and approved as being of suitable Milking Shorthorn type and conformation and rating Good Plus or better under regular classification requirements. Such cows must also have completed a record of production equal to the standard Record of Merit for the breed according to the age of the animal.

Class B—Females only, the progeny of Class A cows and sired by a Registered Milking Shorthorn Bull.

Class C—Females only, the progeny of Class B cows and sired by Registered Milking Shorthorn Bull.

Class D—Females only, the progeny of Class C cows and sired by Registered Milking Shorthorn Bull.

Class E—Females only, the progeny of Class D cows and sired by Registered Milking Shorthorn Bull—are eligible for registry in the official herd book of the American Milking Shorthorn Society and must be entered therein for future registry of progeny as purebreds. Both males and females from Class E dams are eligible for registry.

Scale of Points for Milking Shorthorn Cows

Head: Feminine in character, finely cut, not too short; horns flat and well set on without coarseness at base (if polled, head tapering from a line drawn across it, just above the eyes, to a rounded protuberance on top, as if an orange were under the skin at that point, ears held normally); forehead broad; eyes large and of gentle expression; nostrils wide and expansive; nose clean; throat clearly defined. **10**

Neck: Lean but not weak.......... 4
Withers: Not too wide.......... 4
Shoulders: Flat and sloping.......... 4
Chest: Broad and deep, not running wide at the girth.......... 4
Barrel: Hooped, well ribbed up, and of good depth.......... 10
Back: Broad over the loins, the top line being straight from withers to the tail.......... 5
Hips: Wide apart but not too prominent.......... 4
Rump: Long, broad, and level, with tail fine and neatly set in.......... 6
Hindquarters: Wide, the legs when viewed from behind being straight and without nearness when walking.......... 6
Udder: Well carried, thin skinned with pronounced milk veins, large in capacity (not fleshy or split up between the quarters), extending high up at the back, hanging almost perpendicularly, and running well forward in line with the belly; teats of good and even size, squarely placed and wide apart; milk veins about the abdomen tortuous and highly developed.......... 15
Escutcheon: Even and well defined (there being an absence of coarse hair between its upward growth and the downward growth of the ordinary coat), high and wide horizontal markings in addition to vertical being of especial importance.......... 2
Skin: Mellow, flexible to the touch, fairly thin, carrying a good coat of hair. Patchy and faded colors are to be avoided.......... 8
Flesh: Level, with an entire absence of unevenness or cushions.......... 8
Carriage and Action in Walking: Gay and agile.......... 5
General Appearance: Symmetrical, combining size and scope.......... 5

100

Scale of Points for Milking Shorthorn Bulls

Head: Masculine in character, finely cut, not too short, horns flat and well set on without coarseness at base (if polled, head tapering from a line drawn across it, just above the eyes, to a rounded protuberance on top, as if an orange were under the skin at that point, ears held normally); forehead broad; eyes prominent and lively; nostrils wide and expansive; nose clean; throat clearly defined.......... 10
Neck: Long, arched, muscular, not heavy.......... 4
Withers: Strong but not too wide.......... 4
Shoulders: Flat and sloping, indicating style and liberty.......... 4
Chest: Broad and deep, not running wide at the girth.......... 4
Barrel: Hooped, well ribbed up, and of good length.......... 10
Back: Broad over the loins, the top line being straight from withers to the tail.......... 10
Hips: Wide apart, but not too prominent.......... 4
Rump: Long, broad, and level, with tail neatly set in.......... 6
Hindquarters: Wide, the legs when viewed from behind being straight and without nearness when walking.......... 6
Rudimentary Teats: Well developed, set horizontally, wide apart and away from the scrotum.......... 8
Escutcheon: Even and well defined, the horizontal marking high up, the more pronouncedly vertical the better.......... 2

Skin: Mellow, flexible to the touch, fairly thin, carrying a good coat of hair. Patchy and faded colors are to be avoided.	8
Flesh: Level, with an entire absence of unevenness or cushions.	10
Carriage and Action in Walking: Gay and vigorous.	5
General Appearance: Symmetrical, combining size and scope.	5
	100

Chapter 17

THE RED POLLED

CHARACTERISTICS. THE RED POLLED ARE SMALLER THAN THE SHORTHORN and larger than most of the dairy breeds. The desired weight for mature cows is from 1,300 to 1,500 pounds. Mature bulls should weigh from 1,800 to 2,000 pounds, and individuals sometimes weigh as much as 2,500 pounds. As is indicated by the name, they are hornless. Any sign of horns or scurs disqualifies an animal for registry.

The color may be any shade of red, a cherry red being preferred. Light or very dark shades are not uncommon, but they are not considered desirable by the breeders. No white is tolerated except for the switch of the tail, the udder, and the inguinal region. While dark or cloudy noses are found in the breed, they are considered objectionable. The nose should be a clear flesh color.

Type. The Red Polled is a true dual-purpose breed. (Figs. 36 and 37.) The most desired type in the breed is intermediate between the angular dairy type and the blocky beef type. These cattle are rounded over the withers, have somewhat outcurving thighs, and are generally fairly well covered with flesh. One of the real problems in breeding Red Polled cattle is to keep them midway between the dairy and beef types, as the tendency is to go to either the extreme beef or the dairy type.

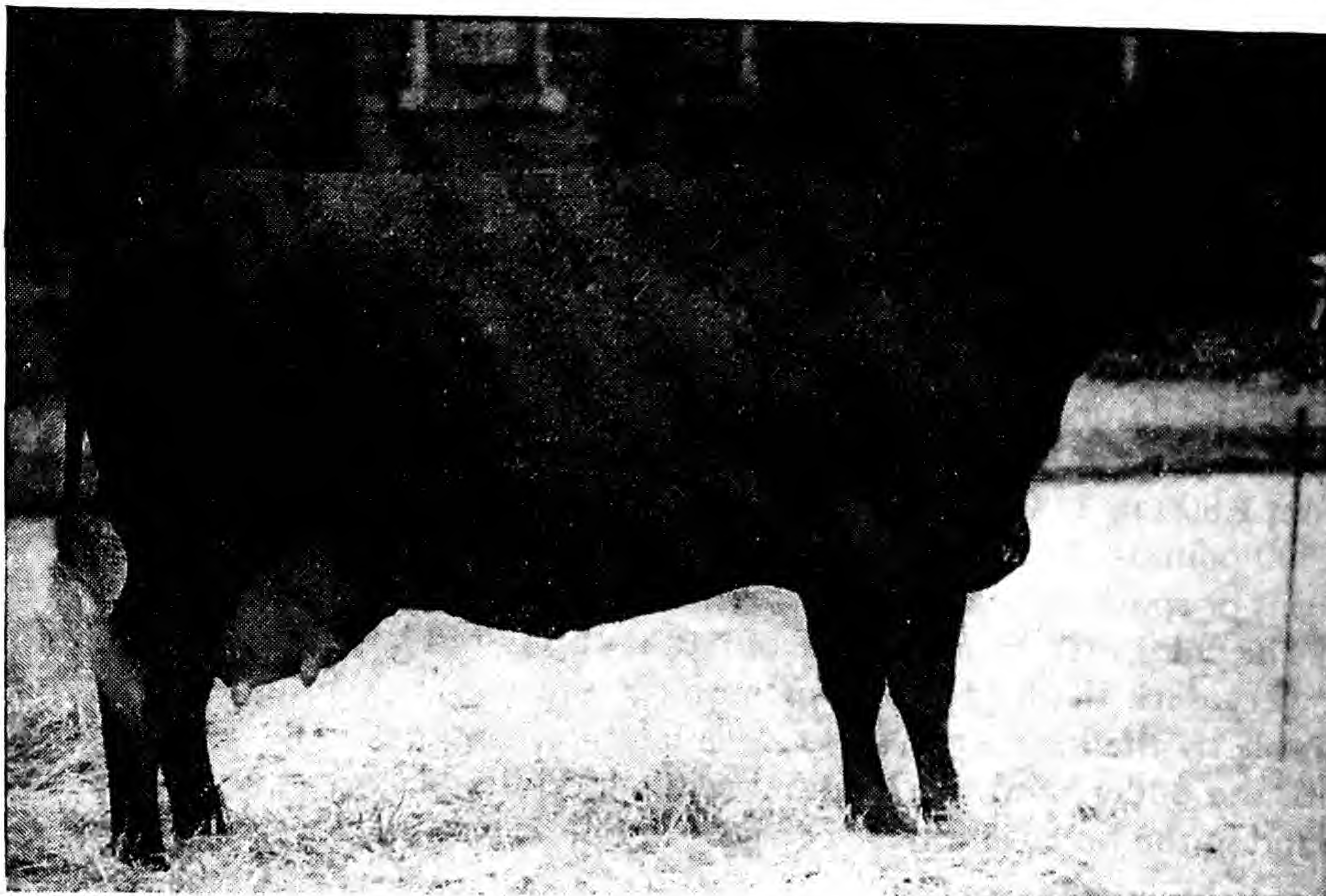
The Red Polled have rather straight lines, and on the average deviate from the true type no more than older established breeds. The udders, however, frequently lack in symmetry, having a tendency to quarter and divide between the halves. The teats are sometimes irregular in shape and not squarely placed upon the udder.

Temperament. The Red Polled are active yet easily handled, and are not easily excited or disturbed; these are points in favor of the breed for ordinary farm conditions. They are generally considered excellent grazers.

Maturity and reproduction. Red Polled are average from the standpoint of maturity. Heifers of normal growth and development come into milk between 27 to 30 months of age. No reliable data are available as to how the Red Polled rank as reproducers.

Meat and veal production. The Red Polled rank high among milking cattle for beef production. The steers are usually blocky and dress out high. Red Polled steers are recorded as having won first place in national carcass contests. When they are through milking, the cows fatten rapidly to produce satisfactory beef. The calves are not so large at birth as are the calves of the Holstein and Brown Swiss breeds, and therefore are not so desirable for veal production, although they rank high in this respect.

Milk. The Red Polled rank lower than any of the strictly dairy breeds for butterfat production. In milk production they exceed only the Jersey



Fred Esterly, the owner

Fig. 36. Cedarview Faith 76022, a Red Polled cow of excellent type, has been grand champion at more than a score of state and national shows, including the International Livestock Exposition.

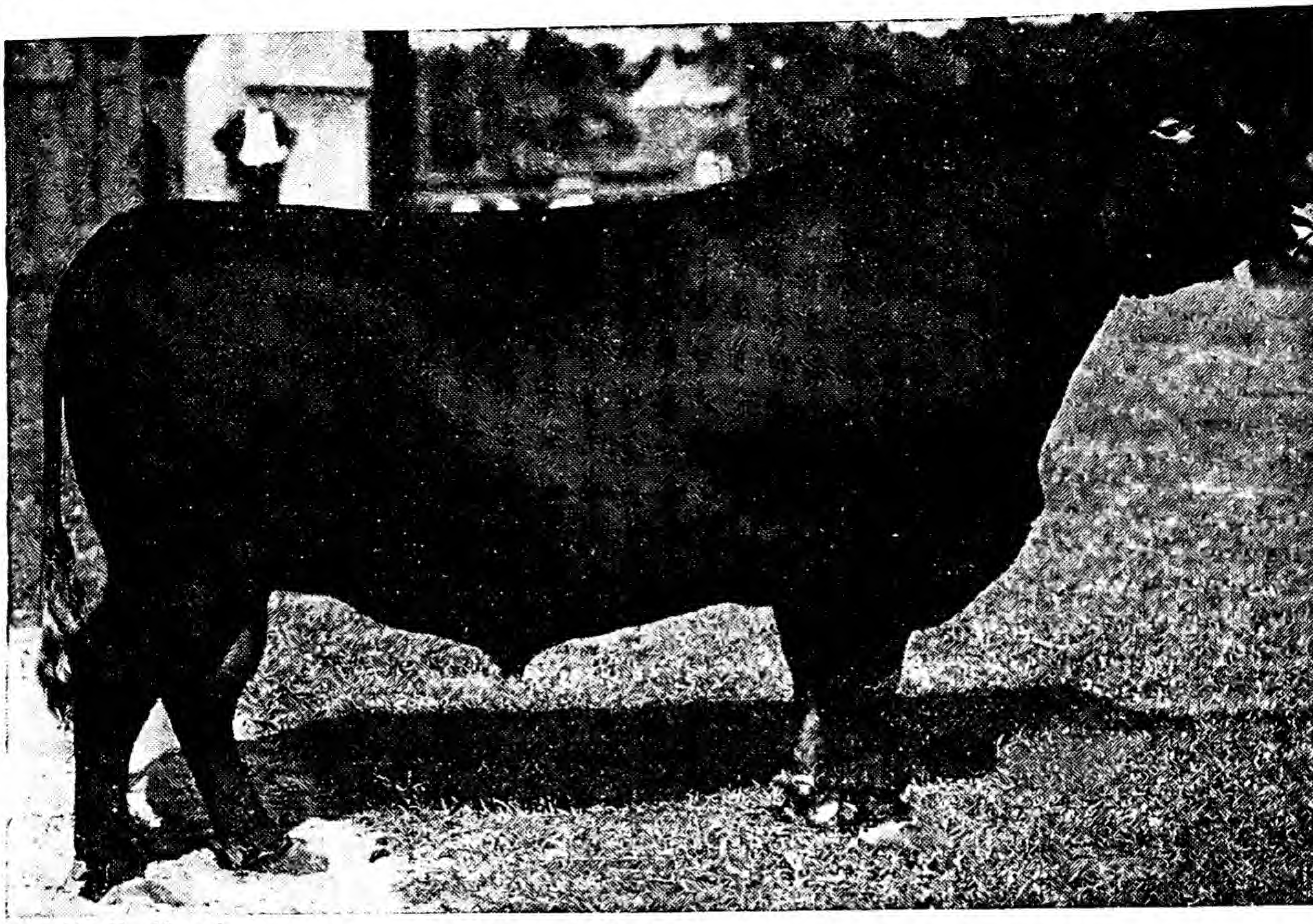
and Guernsey breeds. A good average yearly milk production under average farm conditions is from 5,000 to 6,000 pounds of milk and from 200 to 250 pounds of butterfat.

The milk averages 4.3 per cent of fat; this makes it ideal for market milk, cheese production, or condensed milk. The milk is moderate in color, ranking with the Ayrshire in this respect.

Origin and development. The Red Polled originated and developed in Norfolk and Suffolk counties in eastern England. The foundation stock from which they were developed is unknown. Some claim that the breed has been developed from cattle brought over by the Danes in the fifth century, while others claim that they have been developed mainly from the Galloway breed.

The modern Red Polled is the result of crossing the cattle of Norfolk and Suffolk. Up until 1862 the cattle from these two counties went under separate names—Norfolk Polled and Suffolk Polled. In 1862 they were recognized as one breed and called the Norfolk and Suffolk Polled cattle. In 1882 the name was shortened to the Red Polled.

According to the history of the breed, the cattle in Norfolk were developed along different lines than were those of Norfolk until the beginning of the nineteenth century. From the beginning of the nineteenth century, by intercrossing, the cattle in the two counties became identical. The earliest records show that the Suffolk cattle were exceptional milkers, with the milk having rather low fat content, and that they were polled. They



Dr. E. E. Noack

Fig. 37. A typical Red Polled bull, Redow Barron.

are also reputed to have been of rather extreme dairy conformation.

The early Norfolk cattle, on the other hand, were more rugged and more beefy in character. As late as 1800 the cattle in Norfolk were partly polled and partly horned. They are also reputed to have produced higher testing milk than the Suffolk cattle, although not so much. The crossing of the cattle from the two counties resulted in the breed now known as the Red Polled, the main characteristics of which are intermediate between the dairy and beef breeds.

Importation and distribution. While cattle from both Norfolk and Suffolk were brought over to this country by the earliest settlers, none of them were kept pure. According to Eckles, the early importations of these cattle were responsible for the polled cattle in New England in the early days. The first importation into this country that was kept pure was made in 1873 by G. F. Tabor of New York. Several other importations were made up to 1890 from which the Red Polled in America have been developed.

Excluding their native home, the Red Polled are confined to Australia, New Zealand, and America. In the United States they are confined largely to the Midwest and the Southwest. The states leading in the number of Red Polls are Minnesota, Illinois, Iowa, Michigan, Texas, Kansas, Indiana, Nebraska, North Dakota, and Ohio.

Registration. The records of the breed are kept by the Red Polled Cattle Club of America, which was organized in 1883. The association has no permanent office, the headquarters changing with each change of

secretary. Up to August, 1937, a total of 141,298 head had been registered, of which 83,120 were females and 58,178 were males.

Advanced Registry. In 1908 the Red Polled Cattle Club adopted an Advanced Registry plan. In order to be eligible for entry in the Advanced Register, a mature cow must produce 300 pounds of fat and 6,000 pounds of milk. To date 1,197 cows have qualified. These average 8,827 pounds of milk and 381.2 pounds of fat. (See the following table.)

TEN HIGHEST PRODUCING RED POLLED COWS

Name	Pounds of Milk	Pounds of Fat
Jean Duluth Beauty 31725	20,280.6	891.58
R. L. Josephine 52620	15,310.2	772.14
R. L. Lilly Ella 52624	17,045.7	723.67
R. L. Dorcas 58725	15,313.1	707.36
Jean Duluth Pear 28991	16,598.4	707.24
R. L. Dewie 72432	13,512.2	703.10
R. L. Paulina 62208	14,123.5	700.14
Lula 63235	14,883.5	688.04
Golden Plutie 47408	11,733.9	677.85
R. L. Peggy 72438	16,335.10	631.01

Score cards. The Scale of Points for the Red Polled differ rather fundamentally from the Scale of Points of the strictly dairy breeds in the desired qualifications of many parts. The Red Polled Scale of Points calls for more fleshing, and a rounding of parts that should be angular for the strictly dairy breeds. The red Polled should be rounding over the shoulders and hind quarters, with good covering of flesh over the hips and back. The Red Polled Scale of Points also lays slightly less stress on mammary development.

RED POLL COW SCORE CARD

Ideals of type and breed characteristics must be considered in the application of the terminology of this score card.

1. General Appearance **Perfect Score—30**

Attractive individuality, revealing vigor, femininity with a harmonious blending and correlation of parts. Impressive style and attractive carriage with a graceful walk.

BREED CHARACTERISTICS

COLOR—any shade of red, deep to dark red preferred; the switch of tail may be red, red and white, or white. There may be a limited amount of white running forward to the navel. Nose of clear color; interior of ears should be a yellow waxy color.

SIZE—weight when mature in moderate flesh, 1200 to 1500 pounds.

HEAD—short to medium length, feminine, wide between the eyes, sloping gradually from above the eyes to poll; the poll well defined and prominent with a

sharp dip behind it in center of head; ears of medium size and well carried; eyes prominent; face well dished between the eyes; bridge of nose straight; muzzle wide with large nostrils.

NECK—medium in length, clean cut, and straight from head to top of shoulder.

SHOULDER—medium in thickness, smoothly laid level with line of back.

BACK—strong and straight.

LOIN—broad, strong, and nearly level.

RUMP—long, wide, top-line level from loin to and including tail head.
Hips wide, approximately level laterally with back.
Thurls wide apart.
Pinbones wide apart and slightly lower than hips, well defined.
Tail head slightly above and neatly set between pin bones.
Tail long and tapering with nicely balanced switch.

FEET AND LEGS—

Forelegs—short, nearly straight, wide apart, squarely placed. Feet short and well rounded with deep heel and level sole.

Hind legs—when viewed from the side, nearly perpendicular from hock to pastern. When viewed from rear, legs wide apart, and nearly straight. Bone, medium size, pasterns medium length. Feet short and well rounded with deep heel and level sole.

2. Beef and Dairy Characteristics **Perfect Score—25**

Deep body, short legs, moderately thick, smooth flesh covering.

NECK—medium in length, blending smoothly into shoulder and brisket; clean cut throat and dewlap.

SHOULDERS—well defined, blending smoothly.

LOIN—broad, strong, well covered.

HIPS—wide, rounding, and well covered.

THIGHS—long, wide, medium in muscle development; wide apart when viewed from the rear, providing sufficient room for udder development.

SKIN—medium in thickness, loose, pliable.

3. Body Capacity **Perfect Score—20**

Relatively large in proportion to size of animal, providing ample digestive capacity, strength, and vigor.

BARREL—deep, strongly supported, with spring of ribs arching from backbone.

HEARTGIRTH—large, resulting from long, well-sprung ribs; wide chest floor between front legs; fullness at point of elbow.

4. Mammary System **Perfect Score—25**

A capacious, strongly attached, well-carried udder of good quality, indicating heavy production and a long period of usefulness.

UDDER—

Capacity and *Shape*—long, wide, and of moderate depth; extending well forward, strongly attached, reasonably level floor; rear attachment high and wide; quarters evenly balanced and symmetrical.

Texture soft, pliable, and elastic; well collapsed after milking.

Teats uniform, of convenient length and size, cylindrical in shape, free from obstructions, well apart and squarely placed, plumb.

MAMMARY VEINS—long, tortuous, prominent, and branching, with numerous large wells; veins on udder numerous and clearly defined.

Total Perfect Score—100

EVALUATION OF DEFECTS

In a show ring, disqualification means that an animal is ineligible to win a prize. Any disqualified animal is not eligible to be shown in group classes. In slight to serious discrimination, the degree of seriousness shall be determined by the judge.

EYES—

1. Total blindness: Disqualification.
2. Blindness in one eye: Slight discrimination.

COLOR—Too light or too dark, approaching black: Slight discrimination. Any white spots above the underline, or above the switch of tail; or on the legs: Disqualification. Any white running forward of navel: Serious discrimination.

NOSE—Black: Serious discrimination. Cloudy or spotted: Slight discrimination.

CAPPED HIP—Slight discrimination.

TAIL SETTING—Abnormal tail settings: Slight to serious discrimination.

LEGS AND FEET—

1. Lameness—apparently permanent and interfering with normal function: Disqualification. Apparently temporary and not affecting normal function: Slight discrimination.
2. Bucked knees, blemished hocks, crooked hind legs, weak pasterns: Slight to serious discrimination.
3. Evidence of arthritis, crampy hind leg: Serious discrimination.
4. Enlarged knees: Slight discrimination.

SCURS OR HORNY GROWTH—Disqualification.

LACK OF SIZE—Slight to serious discrimination.

TEMPORARY OR MINOR INJURIES—Blemishes or injuries of a temporary character not affecting animal's usefulness: Slight discrimination.

EVIDENCE OF SHARP PRACTICE—Animals showing signs of having been operated upon or tampered with for the purpose of concealing faults in conformation, or with intent to deceive relative to the animal's soundness: Disqualification.

UDDER—

1. One or more blind quarters: Disqualification.
2. Abnormal milk (bloody, clotted, watery): Possibly disqualification. A slight to serious defect.
3. Udder definitely broken away in attachment: Serious discrimination.
4. A weak udder attachment: Slight to serious discrimination.
5. One or more light quarters, hard spots in udder, side leak or obstruction in teat (spider): Slight to serious discrimination.

DRY COWS—In case of cows of apparently equal merit: Give preference to cows in milk.

Disqualification from Registration

COLOR—Any white spots above underline or above switch of tail, or on the legs.

HORNS—Scurs or any horny growth.

Approved by the Red Poll Cattle Club of America 1944

RED POLL BULL SCORE CARD

Ideals of type and breed characteristics must be considered in the application of the terminology of this score card.

1. General Appearance **Perfect Score—30**

Attractive individuality, revealing vigor, masculinity with a harmonious blending and correlation of parts. Impressive style and attractive carriage with an active, well-balanced walk.

BREED CHARACTERISTICS

COLOR—any shade of red, deep to dark red preferred; the switch of tail may be red, red and white, or white. There may be a limited amount of white running forward to the navel. Nose of clear color; interior of ears should be a yellow waxy color.

SIZE—weight when mature, in moderate flesh, 1800 to 2000 lbs.

HEAD—short, wide, strong, masculine; poll strong, less prominent than on cow; ears of medium size, ears well carried; eyes prominent; forehead broad between the eyes and moderately dished; bridge of nose straight, muzzle wide with large nostrils.

NECK—short to medium in length, full crest, thick, masculine.

SHOULDER—medium thick, smoothly laid level with line of back.

BACK—strong, straight.

LOIN—broad, strong, full, level.

RUMP—long, wide; top line level from loin to and including tail head.
Hips wide, approximately level laterally with back.
Thurls wide apart.
Pinbones wide apart, slightly lower than hips.
Tail head slightly above and neatly set between pinbones.
Tail long and tapering with nicely balanced switch.

2. Beef and Dairy Characteristics **Perfect Score—35**

Deep body, short legs, moderately thick, smooth flesh covering.

NECK—short to medium in length, blending smoothly into shoulders and brisket, brisket carried well forward, clean-cut throat and dewlap.

SHOULDER—of medium thickness and smoothly laid, coming up level with line of back.

LOIN—broad, long, thickly covered.

HIPS—wide, rounding, and well covered.

THIGHS—when viewed from side, wide, moderately full and with fullness carried down close to hock. When viewed from the rear, full and deep on outside, moderately wide apart.

SKIN—of medium thickness, loose, pliable.

TESTICLES—both normal—scrotum normal.

3. Body Capacity **Perfect Score—20**

Relatively large in proportion to size of animal, providing ample digestive capacity, strength and vigor.

BARREL—deep, strongly supported, with spring of ribs arching from backbone

HEARTGIRTH—large resulting from long, well-sprung ribs; wide chest floor between front legs and fullness at point of elbow.

4. Legs and Feet **Perfect Score—15**

FORELEGS—short, nearly straight, wide apart, squarely placed. Feet short and well rounded with deep heel and level sole.

HIND LEGS—when viewed from the side, nearly perpendicular from hock to pastern. When viewed from rear, legs wide apart and nearly straight. Bone, medium size; pasterns medium length. Feet short and well rounded with deep heel and level sole.

Total Perfect Score—100

EVALUATION OF DEFECTS

In a show ring, disqualification means that an animal is ineligible to win a prize. Any disqualified animal is not eligible to be shown in group classes. In slight to serious discrimination, the degree of seriousness shall be determined by the judge.

EYES—

1. Total blindness: Disqualification.
2. Blindness in one eye: Slight discrimination.

COLOR—Too light or too dark, approaching black: Slight discrimination. Any white spots above the underline, or above the switch of tail; or on the legs: Disqualification. Any white running forward of navel: Serious discrimination.

NOSE—Black: Serious discrimination. Cloudy or spotted: Slight discrimination.

CAPPED HIP—Slight discrimination.

TAIL SETTING—Abnormal tail settings: Slight to serious discrimination.

LEGS AND FEET—

1. Lameness—apparently permanent and interfering with normal function: Disqualification. Apparently temporary and not affecting normal function: Slight discrimination.
2. Bucked knees, blemished hocks, crooked hind legs, weak pasterns: Slight to serious discrimination.
3. Evidence of arthritis, crampy hind leg: Serious discrimination.
4. Enlarged knees: Slight discrimination.

SCURS OR HORNY GROWTH—Disqualification.

LACK OF SIZE—Slight to serious discrimination.

TESTICLES—Bull with one testicle or abnormal testicles: Disqualification.

TEMPORARY OR MINOR INJURIES—Blemishes or injuries of a temporary character not affecting animal's usefulness: Slight discrimination.

EVIDENCE OF SHARP PRACTICE—Animals showing signs of having been operated upon or tampered with for the purpose of concealing faults in conforma-

tion, or with intent to deceive relative to the animal's soundness: Disqualification.

Disqualification from Registration

COLOR—Any white spots above underline or above switch of tail, or on the legs.

HORNS—Scurs or any horny growth.

TESTICLES—Only one testicle in purse.

Approved by the Red Poll Cattle Club of America 1944

Chapter 18

THE LESSER BREEDS

WHILE THE BREEDS PREVIOUSLY DISCUSSED MAKE UP NEARLY ALL OF THE strictly dairy cattle in the United States, several other breeds have representatives that are strictly dairy in character. The most important of the minor dairy breeds is the Dutch Belted, followed by the Red Danes, French Canadian, and the Dexter and Kerry breeds.

THE DUTCH BELTED

Characteristics. The chief distinguishing characteristic of the Dutch Belted breed is the silvery white belt around the middle of an otherwise cola black animal. No black is tolerated on this belt, which begins immediately back of the shoulder and sometimes extends back to the hook bones. The only other white on these cattle is the small amount sometimes found on the feet. The belt may be of varying widths, but for the animal to be elgible for registry, is must be at least 6 inches wide at its narrowest point.

The Dutch Belted is a little smaller in size than the Holstein, which they otherwise resemble to a considerable degree. Mature cows weigh from 1,100 to 1,400 pounds, and bulls from 1,600 to 2,200 pounds. As a rule the Dutch Belted is finer boned than the Holstein and not quite so deep of middle. (Figs. 38 and 39.) The calves weigh from 65 to 90 pounds at birth and are vigorous and easy to raise. The body fat is said to be white, making presentable veal and beef carcasses from that standpoint.

The milk, containing 4.0 per cent of fat with low color, resembles that of the Ayrshire. The fat particles are small.

Origin and history. The exact origin of the Dutch Belted is obscure. It is generally believed that they sprang from the black and white cattle of Holland. Some authorities claim that they were in existence as early as the sixteenth century. Until recently they have been entirely in the hands of the nobility in Holland. While so confined, the main objective in breeding was to fix the belted character. In Holland they are known as the Lakenwield breed.

The first importation into the United States was made in 1838. In 1840 the most important importation was made when P. T. Barnum brought over a number of head to be used for show purposes. A total of 69 animals have been imported.

Dutch Belted cattle are found in most states but the numbers are few. New York, New Jersey, and Florida have the largest numbers.

Record keeping. Registration, transfer, and recording of Official Test records is done by the Dutch Belted Cattle Association. This association, organized in 1886, has its offices at Buchanan, Michigan.

In 1920 the Association adopted an Advanced Registry system. Up to January, 1935, 99 cows had been admitted. These average 10,570 pounds of milk, 417 pounds of fat, and a 3.94 fat percentage. The highest record cow of the breed is Loraine of Brunswick, with 816.5 pounds of fat and 18,211 pounds of milk.

Scale of Points for Dutch Belted Cows

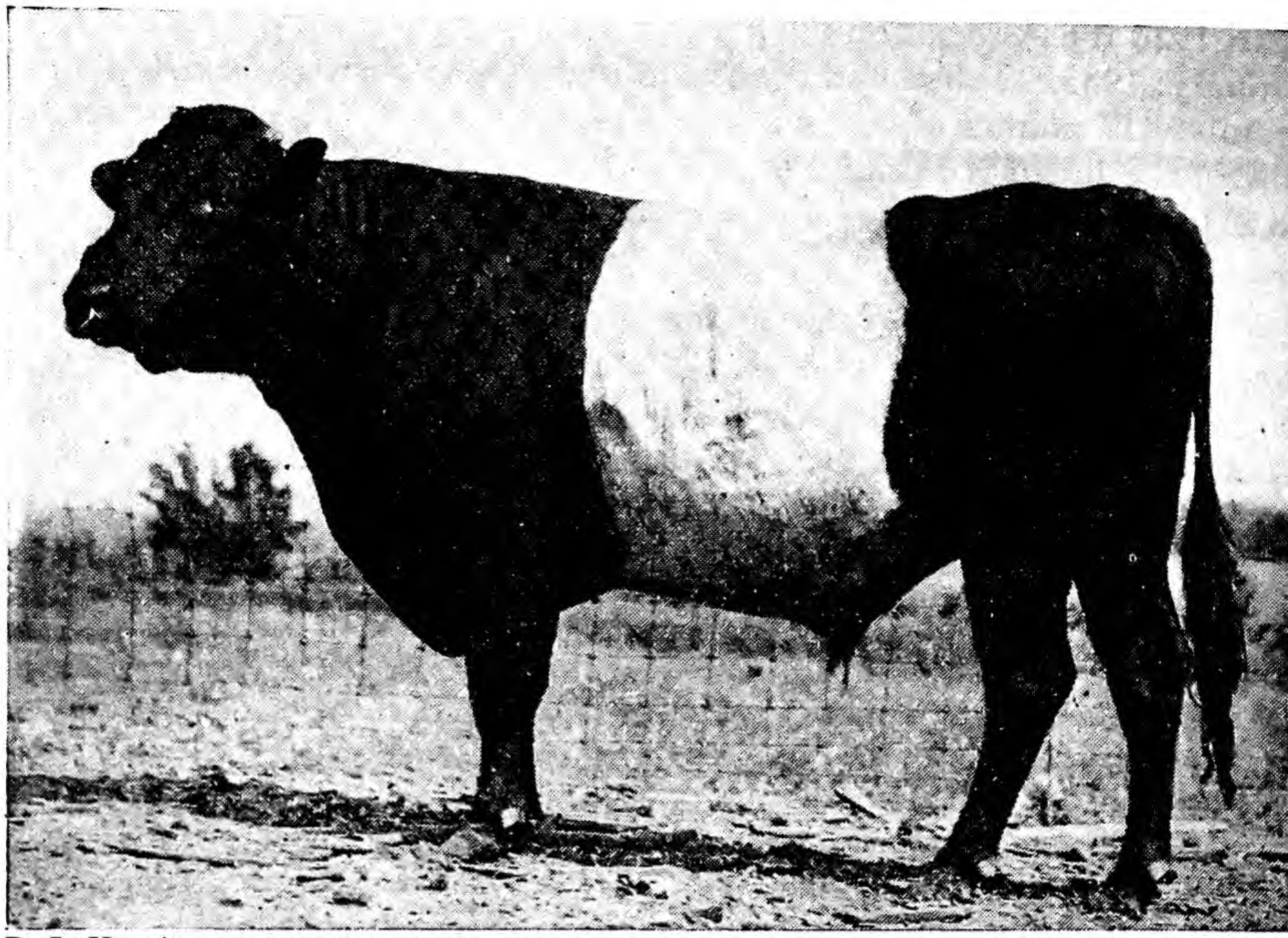
Points		Count
1	Body color black, with a clearly defined continuous white belt. The belt to be of medium width, beginning behind the shoulder and extending nearly to the hips	8
2	Head comparatively long and somewhat dishing; broad between the eyes. Poll, prominent; muzzle, fine; dark tongue	6
3	Eyes black, full, and mild. Horns long compared with their diameter	4
4	Neck fine and moderately thin, and should harmonize in symmetry with the head and shoulders	6
5	Shoulders fine at the top, becoming deep and broad as they extend backward and downward, with a low chest	4
6	Barrel large and deep with well-developed abdomen; ribs well rounded and free from fat	10
7	Hips broad and chine level, with full loin	10
8	Rump high, long, and broad	6
9	Hindquarters long and deep, rear line incurving. Tail long, slim, tapering to a full switch	8
10	Legs short, clean, standing well apart	3
11	Udder large, well-developed front and rear. Teats of convenient size and wide apart; mammary veins large, long, and crooked, entering large orifices	20
12	Escutcheon	2
13	Hair fine and soft; skin of moderate thickness, of a rich dark or yellow color	3
14	Quiet disposition and free from excessive fat	4
15	General condition and apparent constitution	6
	Perfection	100

Scale of Points for Dutch Belted Bulls

The scale of points for males shall be the same as those given for females, except that No. 11 shall be omitted and the bull credited 10 points for size and wide spread and placing of rudimentary teats, and 10 additional points for perfection of belt.

FRENCH-CANADIAN

While there are but few French-Canadian cattle in the United States, this breed merits consideration because it is the only breed of dairy cattle developed in America. The French-Canadian breed has been developed around Quebec from importations of cattle from France made by the early French settlers at Quebec. The breed originates from the Normandy



P. I. Horning

Fig. 38. A typical Dutch Belted bull, King of Lakeview 1743.

and Brittany cattle of France and is, therefore, closely related to both the Guernsey and Jersey breeds.

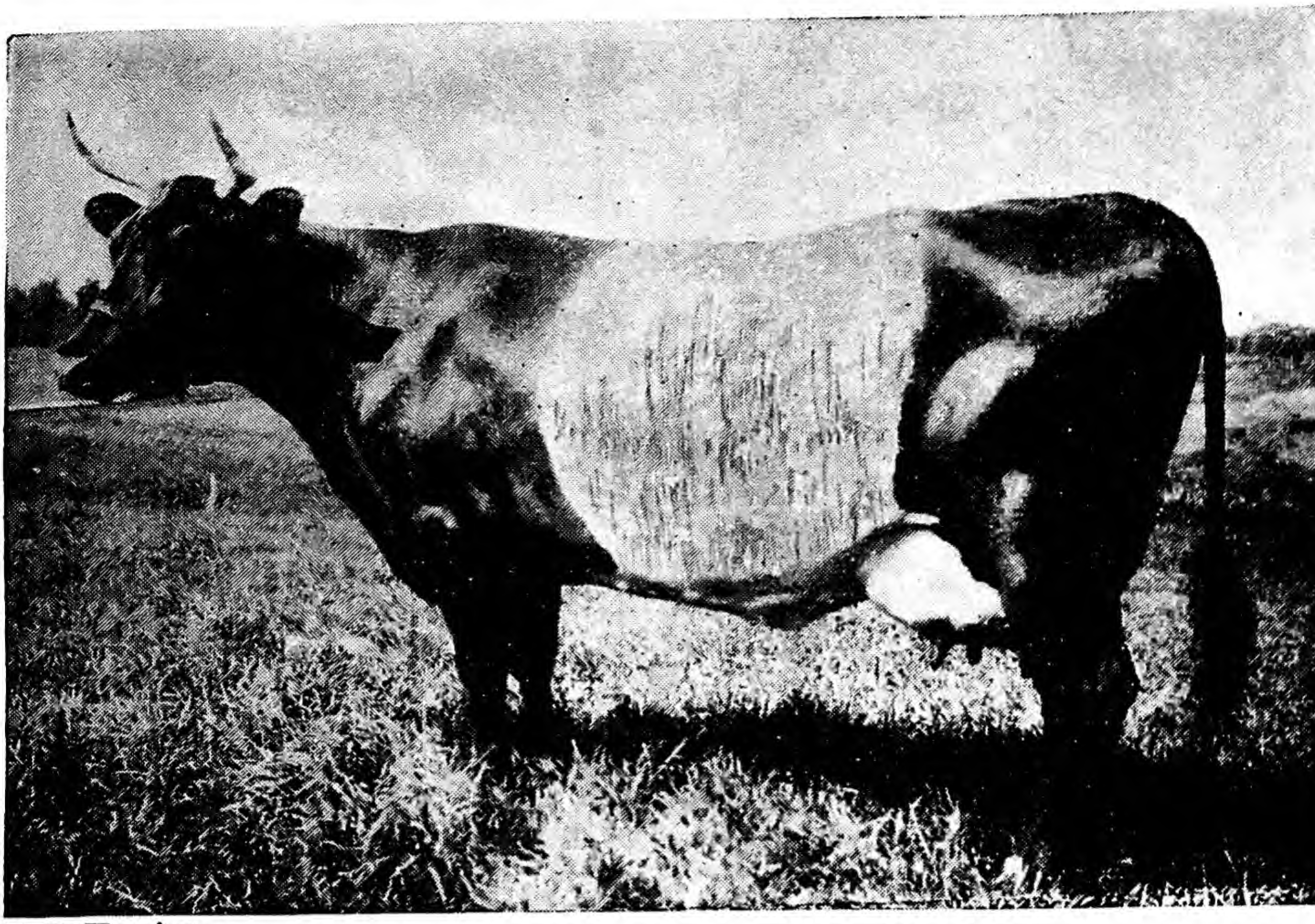
French-Canadian cattle are of the same size and general body conformation as the Jersey. They are, however, somewhat rougher, and the udders lack the symmetry of the Jerseys. They are very hardy and excellent grazers. The milk averages 4.5 per cent fat. In color they are mostly solid black, although some individuals have a light band around the muzzle and a light strip along the back.

In certain parts of the Province of Quebec, French-Canadian is the predominating breed. A few are found in the northeastern part of the United States. There is no registry association in the United States. In Canada the affairs of the breed are looked after by the French-Canadian Herd Book Association, with headquarters in Quebec. An Advanced Register was established in Canada in 1907. No large records have as yet been reported.

THE DEXTER AND THE KERRY

The Dexter and the Kerry deserve mention because at one time there was a registry association for these two breeds of cattle in the United States. The association has been disbanded for several years because of lack of interest in these breeds.

The Kerry originated in Kerry County, Ireland, where it is favored by small farmers. It is somewhat smaller than the Jersey, averaging about



P. I. Horning

Fig. 39. A typical Dutch Belted cow, Gloria 3231 has a record of 16,546 pounds of milk and 780 pounds of butterfat made when three years of age.

900 pounds and is clean cut and of strictly dairy conformation. These cattle are solid black, except for occasional white spots in the inguinal region and on the udder. They produce a moderate amount of milk averaging about 4 per cent fat.

The Dexter is an offshoot of the Kerry and differs from it in that the legs are much shorter and the total size somewhat smaller. The mating of Dexter to Dexter produces on an average one Kerry, two Dexters, and one so-called "Bulldog" calf which is born prematurely and dead. A recessive gene when present in the homozygous condition is responsible for the Bulldog calf. When in the heterozygous condition this gene is responsible for the short-legged condition that is characteristic of the Dexter cattle.

THE RED DANES

The dominant breed of dairy cattle in Denmark is the Red Dane. This breed was developed in Denmark to suit the special conditions of that country. The Red Dane is solid red and horned. Because of long selection and breeding the Red Danes in their native country are uniform in size, type, and in the characteristics of their milk. The fat percentage of the milk is 4 per cent. The more highly developed dairy breeds will have members that exceed the best of the Red Danes in production capacity

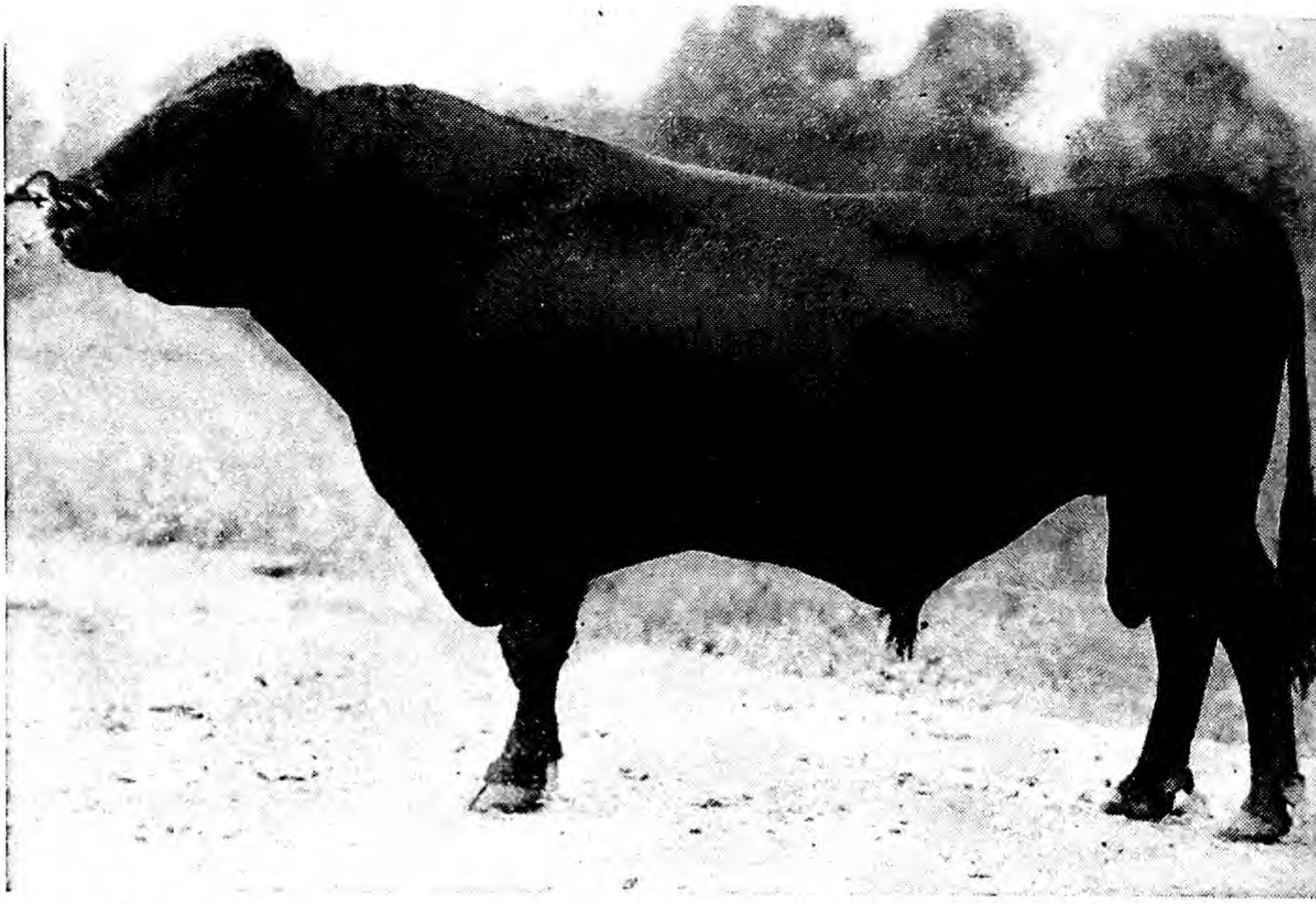


Fig. 40. This is a typical Red Dane bull.

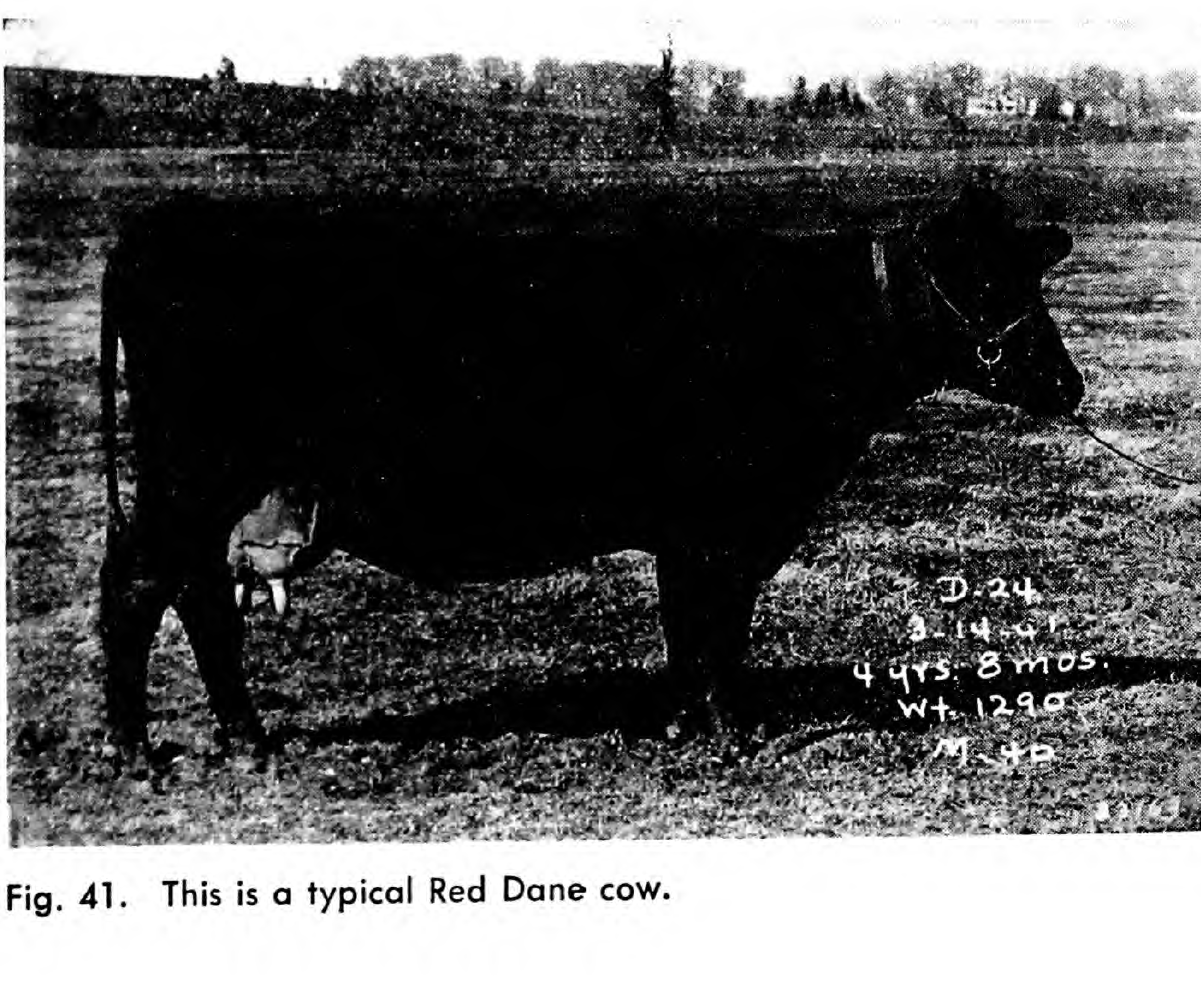


Fig. 41. This is a typical Red Dane cow.

but it is alleged that there are fewer poor producers among the Red Danes.

In 1936 the United States Department of Agriculture imported 20 females and 2 males of selected breeding from Denmark for cross-breeding purposes. Bulls developed from this project have been used on dairy farms, particularly in Michigan, in crosses on grade cattle. A sizeable number of cattle has now been developed that are descendants of these original imported Red Dane cattle. In December, 1945, a registry association was formed at East Lansing, Michigan, known as the American Red Danish Cattle Association.

All third cross females and fourth cross males are eligible to registry in this Association. Females cannot be registered until they have a record of production.

Chapter 19

TYPES OF DAIRY FARMING AND BREED SELECTION

BEFORE DISCUSSING THE CHOICE OF A BREED FOR DAIRY PURPOSES, IT IS well to consider the different types of dairy farming, as the choice of a breed is influenced to a certain extent by the type of dairying that is to be practiced. Dairy farming varies widely with different conditions. Although not all dairy farms can be put definitely into any one of the different classes, in general dairy farms may be classified on at least three bases: the intensity with which dairying is practiced, the kind of cattle used, and the product marketed.

DAIRY FARMS

On the basis of intensity. On the basis of intensity dairy farms may be divided into three groups. These groups are specialized dairy farms, diversified farms, and farms where dairying is but a side line.

The specialized dairy farms are those on which the major or sole income is derived from the dairy. This type of farm is common around large cities, to which it supplies milk, in the dairy regions where cheese and condensed milk are made, and in many sections where butter is produced. Some of the specialized dairies produce no feed. These dairies are usually located close to large cities with good markets, where the land is too expensive to use for producing feed for cattle. The increased cost of production incurred by having to purchase all the feed used is offset by favorable location to the market. Another group of specialized farms grows only the roughage needed for the dairy and purchases most or all of the concentrate feeds. These farms, too, are usually located near large cities where the acreage is limited. A third group produces all the feed needed for the dairy. The specialized dairy farms in the Midwest fall largely into this group. On farms of this type the size of the herd is determined by the amount of feed that can be grown on the land. It is on this type of dairy farm that the most economical production of milk is possible.

Diversified dairy farms are those on which dairying is not the sole source of income but constitutes one of the important sources of revenue. This type of farm is very common in the corn belt. In addition to income from the dairy, such other farm enterprises as growing hogs, poultry, horses, sheep, and cash crops are important sources of income.

The third type of dairy farm is that on which the income from the sale of dairy products is merely incidental. It may come from surpluses of a few cows kept mainly to supply the household with milk and cream. Farms producing beef cattle may milk a few of the higher producing cows and sell the cream. Frequently such farms milk cows only when the butter-

fat prices are high or when other sources of income from the farm have failed. Others practice milking a few cows year in and year out regardless of the price condition. This type of dairy farm, found chiefly in the Western and Southwestern states, constitutes an important source of butter.

On the basis of kind of cattle kept. Dairy farms may be classified on the basis of whether the cows are raised on the farm or are purchased for the herd. Farms on which dairy cattle are raised fall into three classes, depending upon whether purebreds, grades, or nondescripts are raised.

Purebreds comprise 4.7 per cent of all dairy cattle, according to government estimates.[1] They are important not because of numbers, but because grade herds, which produce a large part of the dairy products of the country, are dependent upon purebred bulls for existence. There are several types of purebred herds. With some herds the sale of milk or cream is the main source of income, and the sale of surplus cattle is more or less incidental. With others the emphasis is placed upon the sale of breeding stock, and the income from the sale of milk and cream becomes more incidental. Some are kept as a fancier's hobby, elaborate setups being maintained for the production of show cattle as the chief objective. Those fanciers who carry on a sound breeding program for breed improvement do so often at great expense in costs of herd bulls and testing expense, but they do render outstanding service to the dairy cattle enterprise.

Grades comprise from 80 to 85 per cent of all dairy cattle in this country and are the source of a larger proportion of the total milk and cream supply. The majority of specialized dairy farms are stocked with grades of the special dairy breeds; these grades comprise about two-thirds of all grade dairy cattle. The other third of the grade population consists of members of the dual-purpose types.

Nondescripts are cattle lacking sufficient of the characteristics of any breed to be classified as belonging to a breed. This group comprises about 11 per cent of the total dairy cattle population of the United States. In this group are found the lowest producers and in general the most undesirable of dairy cattle. While members of this group are found everywhere, they are the most common on the nonspecialized dairy farms.

On the type of dairy farm on which no calves are raised, all milking cows are purchased either as springers or as fresh cows. When the milk production of any cow drops below the point of being profitable, the cow is sold for slaughter, and a fresh cow is purchased for replacement. This type of dairying is limited to the production of market milk.

On the basis of the type of market. All dairy farms can be classified as selling either milk or cream. A few sell both.

Whole milk is sold from the farm for market milk, cheese manufacture, condensed milk, casein, and dried milk. Approximately one-half of the milk produced for sale is sold off the farm as whole milk. Farms where all the milk is sold as whole milk are located chiefly around large cities and in cheese-producing and condensed-milk areas. In some butter-producing

[1] NYSTROM, A. B. U. S. Dept. Agr. Bul. 1443.

areas the cream is sold for butterfat, and part or all of the skim milk is sold for the manufacture of dried skim milk and casein.

About one-half of the milk produced for sale is used for butter making; it is sold either as cream to butter factories or in the form of butter made on the farm. Where this is practiced, the skim milk is available on the farm for feeding purposes. Farms in this class usually keep poultry or hogs to utilize the skim milk.

CHOOSING THE DAIRY BREED

The most important consideration in establishing a high producing herd of dairy cattle is the individual animal. The variation between individuals within any one breed is infinitely greater than variations between breeds. There are, however, a number of factors of considerable importance to be taken into account when selecting a dairy breed. The important considerations, as well as of some of the claims for superiority that cannot be substantiated, made by some breed organizations, are given under the following headings:

1. Personal preference
2. Breed predominating in the community
3. Type of market
4. Climate
5. Grazing
6. Demand for surplus stock
7. Efficiency of digestion
8. Maintenance requirements
9. Utilization of roughage
10. Vigor of calves
11. Early maturity
12. Beef value of cows
13. Dual-purpose cows

Personal preference. One is likely to become enthusiastic over a breed for which he has a personal preference, and enthusiasm may be the deciding factor in carrying the enterprise through to success. Most people who like livestock are capable of transferring their personal preferences from one breed to another. However, some people are so prejudiced in favor of one breed, because of early contacts with that breed, that it is difficult for them to do anything but criticize the other breeds.

Breed predominating in the community. Anyone starting dairy farming would do well to select the predominating breed in the community. Breeders of one breed of cattle naturally fall into a fraternity because of the many common interests, and there are many advantages in being a member of such a fraternity. Again, the breed most prevalent in the community has considerable advantage when surplus cattle are to be marketed. Buyers are more likely to come to a community where there are large numbers of the breed of cattle in which they are interested. To name the communities in the United States that have become famous for their cattle would require a volume. In Wisconsin, for instance, Ft. Atkinson, Fond du Lac, and Barron County are known all over the United States for the numbers and quality of their cattle. In the case of these communities, where dairying is by far the major farm enterprise, both Guernseys and Holsteins are found. In Minnesota the Northfield community has confined its efforts to the Holsteins. Because of concentration

on this one breed, it has become nationally famous; cattle from this community have been sold to practically every state in the Union and to several foreign countries.

Type of market. That some dairy breeds are better adapted for certain markets than others cannot be questioned. For butter production there is no particular advantage of one breed over another. It is true that the higher testing breeds produce butterfat at a lower cost per pound than do the lower testing breeds; but to compensate for this, the lower testing breeds produce more skim milk, which has additional feed value on the farm. For cheese production the higher testing breeds are not so well adapted, as it becomes necessary to remove part of the fat in order to have the correct proportion of fat to solids-not-fat. Breeds testing 4 per cent or less are the best fitted for cheese production. The proportion of fat to solids-not-fat in condensed milk is the same as for cheese; therefore, the breeds best adapted for cheese production are likewise best adapted for the production of condensed milk.

For market-milk production there are conditions under which any one of the breeds may be best adapted. Where the fat standard is 3.5 per cent and where a small differential is allowed for the excess fat in the milk, the lower testing breeds have a decided advantage. In milk markets where the differential for increased fat content is sufficiently large to adequately compensate for the additional cost of high testing milk, the low testing breeds have no advantage over the high testing breeds.

Around many population centers there are opportunities to develop markets for special milks at good prices. Different breed associations through advertising campaigns have developed special demands for the milk from their particular breed. The Guernsey and Jersey breed associations have respectively copyrighted "Golden Guernsey" and "Cream Line" as trade names for the two milks. Anyone located near a market where sales for either one of these have been developed would do well to investigate the possibilities before making the choice of a breed.

Recently some breed associations have made claims that their breed produces milk with a lower curd tension than that of other milk, and that it is, therefore, more easily digested. Although it has been demonstrated that there are marked variations in the curd tension of the milk as between individual cows, there are too few data available at the present time to say that one breed is superior to another in this respect.

Climate. While adaptation to climate is not a major consideration in the selection of a breed, there are differences in the abilities of breeds to withstand different climates. For hot climates the small breeds are distinctly superior; they have a larger body surface per unit of weight than larger breeds, and therefore are more efficient in getting rid of surplus heat. The breeds of black color absorb more heat from the sun than the lighter colored breeds, and consequently suffer more from heat. The larger animals are able to stand cold better than the smaller ones, since their body surface is proportionately smaller and they lose heat less rapidly. However, with the modern housing conditions the larger breeds

have no particular advantage over the smaller ones in this respect. Some of the most successful Jersey farms are found in the northern part of Canada, where the winters are extremely cold.

Grazing. Considerable differences have been noted in the abilities of breeds in grazing. All the reasons for this are not clear. The larger animal has greater feed needs and consequently must cover more ground to satisfy its nutrient requirements; therefore it would not be expected to do as well on pasture as the smaller animal. However, the Brown Swiss, one of the largest of the breeds, is regarded as one of the best of grazers.

The Ayrshires, medium in size, would possibly rank first. This can be accounted for by the fact that they have been developed in a country of scant pasture, and that only those having superior grazing abilities would be selected for breeding purposes. However, the Jersey, an excellent animal as a grazer, has been brought up under ideal grazing conditions. The Guernsey, brought up under similar conditions and of approximately the same size, is not as good a grazer as the Jersey. Where pastures are luxuriant, there is no difference in breeds in regard to grazing. Where pastures are scant the differences in grazing ability are sufficient to merit serious consideration in the selection of a breed.

Demand for surplus stock. For the breeder of purebred cattle the demand for his surplus stock is a most important consideration, as a good share of the revenue from a purebred establishment may come from the sale of stock for breeding purposes. The demand for surplus stock is inversely proportional to the supply. During the depression years, it was observed that the Guernsey and the Brown Swiss breeds experienced the least decline in prices, chiefly because the numbers of these two breeds are much smaller than for Holsteins and Jerseys.

Efficiency of digestion. While different breed associations have made claims for superior powers of digestion for their particular breed of cattle, the evidence clearly shows that there are no breed differences in the ability to digest food.[1]

Maintenance requirements. Food for maintenance is in direct proportion to the size of the animal, and the requirements for maintenance are definitely known. According to the revised Haecker feeding standard,[2] 7,000 pounds of total digestible nutrients are needed daily for the maintenance of 1,000 pounds live weight. The larger breeds, therefore, need more food for maintenance than do the smaller ones. The Holsteins require from 20 to 30 per cent more feed for this purpose than do the Jerseys, and must produce proportionately more in order to be as economical converters of feed nutrients into milk nutrients.

Utilization of roughage. In the utilization of roughage, different breed associations have claimed superiority for their breed. Adequate data to prove or disprove this are lacking. However, it is questionable that any breed is superior to another breed in its ability to consume and utilize roughage. In 1912 Woll, studying the relative amount of grain and

[1] ARMSBY, H. P. *The Nutrition of Farm Animals*. The Macmillan Co., New York. 1917.
[2] Minn. Agr. Expt. Sta. Bul. 218. 1938.

roughage used by different breeds on farms in Wisconsin, found that 47.6 per cent of the digestive nutrients came from roughage for the Holsteins, 53.1 per cent for the Guernseys, and 59.8 per cent for the Jerseys. These figures are subject to criticism because the Holsteins had much higher yearly production than did either the Jersey or Guernsey and, therefore, had been fed concentrates more liberally. Savage found that Holsteins obtained 52.8 per cent and Jerseys 51 per cent of their nutrient from roughage. The latter figures too, are subject to criticism, in that they did not measure the maximum roughage-consuming abilities of the breed. At the Minnesota Station when cows were allowed roughage only, great individual variation was found; but there were no differences that could be attributed especially to breed differences. In the main, the larger animal is able to consume more roughage than the smaller one, but the true criterion of utilization of roughage is the amount consumed per hundred pounds of live weight. At the Minnesota Station the Holstein and the Jersey were found to be alike in this respect.

Vigor of calves. From the standpoint of the average farmer the strength and vigor of calves at birth and the ease of raising are very important considerations. The losses of calves are as a rule high on farms. The Brown Swiss are outstanding in the strength and vigor of the calves; the Holsteins and the Ayrshires are next; and the Jersey and the Guernsey follow with the weakest calves.

Factors involved in veal production are discussed under another heading. However, for some conditions the production of veal may be an important economic item. Only the larger breeds are to be considered for veal production. The calves of small birth weight require too long a time and too much milk to bring them to marketable weights for veal.

Early maturity. Early maturity is a consideration not often given attention; nevertheless it is important from an economical standpoint. The cost of growing an animal into production age is a very important item. The longer it takes to grow an animal, the greater the cost; and since as the animal increases in age there is a constant increase in cost of maintenance, the last two months may cost more than the three preceding months. Because the larger breeds mature later than the smaller ones, there is considerably more invested in them at production age. In addition to this, the larger breeds cost more for the same age. Henderson, Bowling, and Hermann studied the cost of raising heifers to 24 months of age and found that Holsteins cost $103.17 and Jerseys $94.61.[1] Since Jerseys come into milk at this age, the figure represents the cost of raising to milk producing age; and since four additional months are required to bring the Holstein to milking age, an added cost is incurred, bringing the total to $130.00. Part of the increased cost of growing the larger animal will be recovered in the increased sales value when the animal is through producing; therefore not all the differences in cost of raising can be charged as net increases.

[1] HENDERSON, BOWLING, AND HERMANN. *Amounts of Feed and Labor Used in Raising Dairy Heifers*. W. Va. Agr. Expt. Sta. Bul. 277.

Beef value of cows. Some, when selecting a breed for dairy purposes, lay undue emphasis upon the value the cow will have as beef when it is disposed of. That such beef is produced uneconomically becomes apparent when one considers all the facts. The average productive life of a dairy cow is five years; therefore cows are disposed of at an average age of seven years. The feed required for maintaining a pound of beef for this period costs far more than will be realized from the sale even on a favorable market. The producers of beef cattle realize the high feed costs for maintenance, and therefore grow their beef animals into marketable size as rapidly as possible.

Another objection to selecting dairy cows with beef tendencies is that such animals are seldom as good milk producers as are those of strictly dairy conformation. Feed cannot be used for both beef and milk production at the same time. Animals with beef tendencies are naturally inclined to divide the use of the feed between beef production and milk production, resulting in less economical use for either one.

Dual-purpose cows. A dual-purpose cow or breed is one that is intermediate for both beef and milk production, between strictly beef and milk animals or breeds. As has been shown, these cows are neither so economical as producers of beef as are strictly beef cows, nor so economical as producers of milk as are strictly dairy cows. The champions of dual-purpose cattle claim special adaptability of this type to general farms. The claims of superiority of dual-purpose in addition to the greater beef value of the cows are:

1. Dual-purpose cows are more rugged and require less attention than the specialized dairy cows.
2. The calves are more easily raised.
3. The calves are grown into more valuable beef animals.
4. Dual-purpose animals permit a shift from dairy to beef or vice versa.
5. Dual-purpose cattle make greater use of roughage.

On the large farms where the facilities for dairying are limited and it is advisable to have a large herd of cattle, these claims are valid. Lower producing cows do not require the attention in feeding and care that high producing cows do. Neither do they require as good housing. The dual-purpose breed can make a higher proportion of the total production on roughage than can the high producing specialized dairy breeds.

While the calves from dual-purpose cattle may not be easier to raise, they have greater meat values than calves from the specialized dairy breeds. This is of particular value on large farms where a large portion of the calves raised are to be used for beef production.

Chapter 20

SELECTING THE INDIVIDUAL COW

THE FIRST ESSENTIAL IN ESTABLISHING AND MAINTAINING A PROFITABLE and desirable dairy herd is intelligent selection of the individual animals. Whether cows are to be purchased or raised on the farm, the problem of selecting the cows for the milking herd is always present, and to a large extent the success of the dairy enterprise depends on the judgment used in the selection. Cows may be selected on one or more of the following three bases: on production of milk and butterfat as indicated by records, on pedigree or the records of the parents, and on appearance or type.

BASIS OF SELECTION

Production records. Records of production offer the most reliable means for selecting profitable cows. An experienced judge of dairy cattle is able to select very poor cows from good ones by their appearances. In the average dairy herd, however, the problem is to select the better cows from more mediocre ones, and this cannot be done from appearance even by the most skilled judges. The relationship between the level of production and profit and the factors influencing milk production will be discussed in other parts of this book. At this point it will suffice to state that, other things being equal, the more milk and butterfat a cow produces, the more profitable she will be.

In evaluating production records of a cow, care should be taken to ascertain the conditions under which the records were made. Good cows may have low production records because they were improperly fed and cared for, and poor cows may have comparatively better records because they were unusually well fed and cared for. Cows with records of 600 or more pounds of fat per year made on three or four times daily milking and heavy grain feeding may not produce over 300 to 400 pounds of fat on twice a day milking and ordinary good care. Sickness and other adverse conditions may also contribute to lowering the production record of a cow. Such records are not representative of the producing abilities of cows, and should be given careful consideration in selecting or eliminating cows.

Pedigree. Dairy animals, bulls in particular, are often selected on the basis of pedigree. This is done with the belief that "like begets like" and offspring, therefore, possess the good qualities of their parents. The pedigree may be a valuable and fairly reliable guide in the selection of individuals, but more often than not it falls short of having any real value in evaluating the producing capacity of the individual concerned. For the breeder of purebred cattle, consideration of the pedigree is essential for a number of reasons that are discussed in other parts of this book.

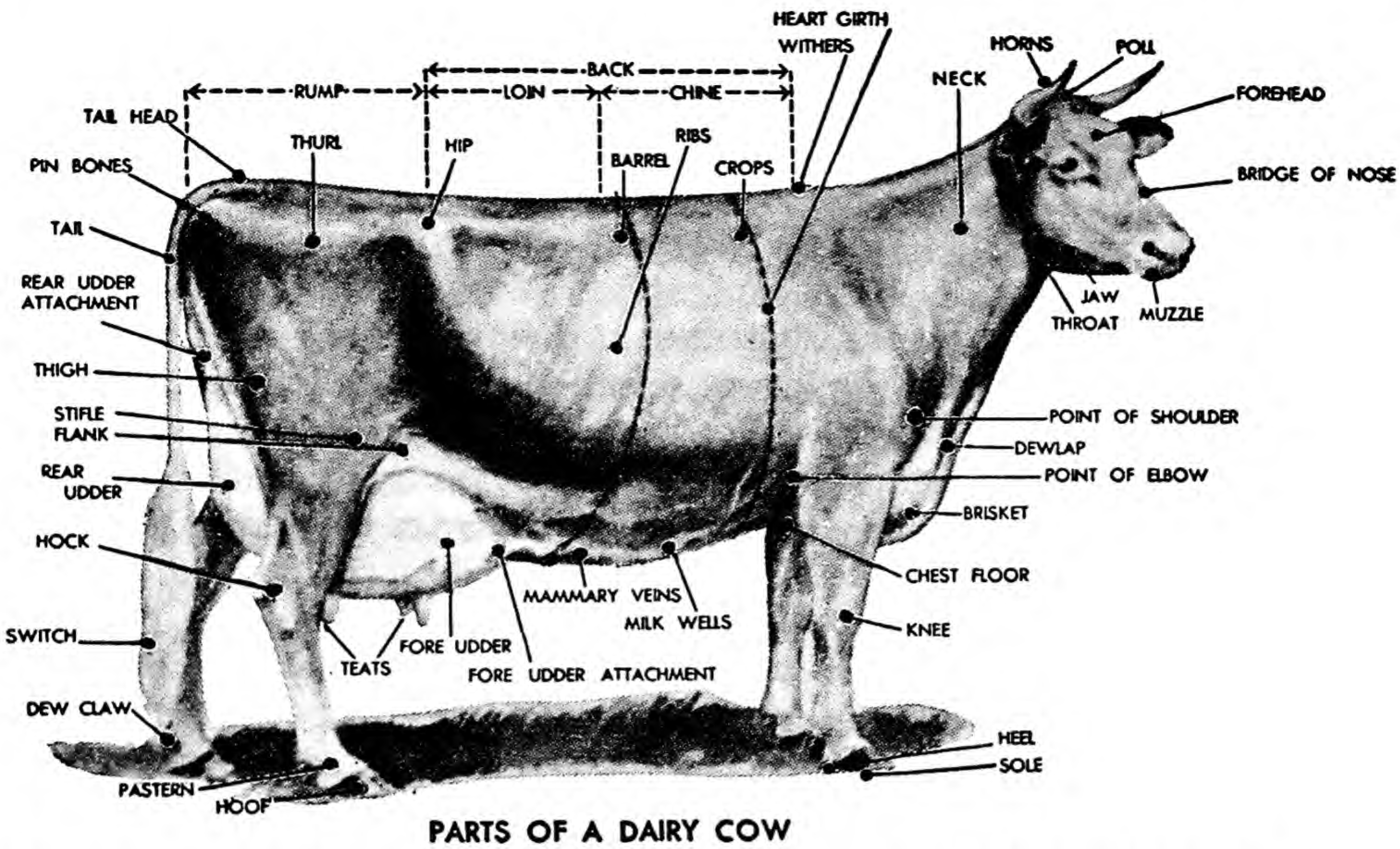


Fig. 42. Parts of the cow referred to in the score card are shown here.

Appearance. Dairy cows are bought and sold on the market mainly on the basis of appearance. While experts are able to select large numbers that will average high production, this method is not reliable for individual selections except for certain types that are certain to be poor producers. Animals of the type illustrated in Figure 42 are certain to be poor and unprofitable producers. Cows of good dairy conformation may not be high producers.

A knowledge of what constitutes good dairy conformation and type, however, is essential to the student of dairying and the breeder of dairy cattle—not because such knowledge enables one to select high producing from low producing cows, as is usually claimed, but because it is desirable to recognize and breed dairy cattle of the approved type. Over a period of time certain standards have been set as to the approved type of the various dairy breeds. The approved type is to be admired more from an esthetic standpoint than as an indication of producing ability. The approved dairy type, therefore, while not in conflict with what is required for high production, is not necessarily an assurance of high production but something to be valued for the sake of beauty.

MAJOR CONSIDERATIONS OF DAIRY TYPE

In order to properly evaluate the type of an animal it is necessary to be familiar with the different anatomical parts and their correct form. The Purebred Dairy Cattle Association has compiled score cards for both bulls and cows that is applicable to all dairy breeds. These score cards have the approval of the American Dairy Science Association. Outlines of both

EVALUATION OF DEFECTS

In a show ring, disqualification means that the animal is not eligible to win a prize. Any disqualified animal is not eligible to be shown in the group classes. In slight to serious discrimination, the degree of seriousness shall be determined by the judge.

EYES
1. Total blindness: *Disqualification.*
2. Blindness in one eye: *Slight discrimination.*

WRY FACE
Serious discrimination.

PARROT JAW
Slight to serious discrimination.

SHOULDERS
Winged: *Slight to serious discrimination.*

CAPPED HIP
Slight discrimination.

TAIL SETTING
Wry tail or other abnormal tail settings: *Slight to serious discrimination.*

LEGS AND FEET
1. Lameness—apparently permanent and interfering with normal function: *Disqualification.*
   —apparently temporary and not affecting normal function: *Slight discrimination.*
2. Bucked knees, blemished hocks, crooked hind legs, weak pasterns: *Serious discrimination.*
3. Evidence of arthritis, crampy hind leg: *Serious discrimination.*
4. Enlarged knees: *Slight discrimination.*

ABSENCE OF HORNS
No discrimination.

LACK OF SIZE
Slight to serious discrimination.

UDDER
1. One or more blind quarters: *Disqualification.*
2. Abnormal milk (bloody, clotted, watery): *Possibly disqualification. A slight to serious defect.*
3. Udder definitely broken away in attachment: *Serious discrimination.*
4. A weak udder attachment: *Slight to serious discrimination.*
5. One or more light quarters, hard spots in udder, side leak or obstruction in teat (spider): *Slight to serious discrimination.*

DRY COWS
In case of cows of apparently equal merit: *Give preference to cows in milk.*

OVERCONDITIONED
Serious discrimination.

TEMPORARY OR MINOR INJURIES
Blemishes or injuries of a temporary character not affecting animal's usefulness: *Slight discrimination.*

EVIDENCE OF SHARP PRACTICE
1. Animals showing signs of having been operated upon or tampered with for the purpose of concealing faults in conformation, or with intent to deceive relative to the animal's soundness: *Disqualification.*
2. Heifer calves showing evidence of having been milked, in an attempt to deceive regarding natural form of udder: *Serious discrimination.*

the bull and the cow with location of the anatomical parts concerned in judging accompanies the score card. The score cards also list defects that are disqualifying and notes on special characteristics for the individual breeds.

Dairy Cow Score Card

Ideals of type and breed characteristics must be considered in the application of the terminology of this score card

Based on Order of Observation		Perfect Score	Cow Under Observation	Official Score
1. GENERAL APPEARANCE		30		
Attractive individuality, revealing vigor, femininity with a harmonious blending, and correlation of parts. Impressive style and attractive carriage with a graceful walk.				
BREED CHARACTERISTICS (see below)	12			
HEAD—medium in length, clean-cut; broad muzzle with large open nostrils; lean, strong jaw; full, bright eyes; forehead broad between the eyes and moderately dished; bridge of nose straight; ears medium size and alertly carried.	—			
SHOULDER BLADES set smoothly against chest wall and withers, forming neat junction with the body.				
BACK strong and appearing straight with vertebrae well defined.				
LOIN broad, strong, and nearly level.				
RUMP long, wide; top-line level from loin to and including tail head.	10			
HIPS wide, approximately level laterally with back, free from excess tissue.				
THURLS wide apart.				
PINBONES wide apart and slightly lower than hips, well defined.				
TAIL HEAD slightly above and neatly set between pinbones.				
TAIL long and tapering with nicely balanced switch.	—			
LEGS wide apart, squarely set, clean-cut, and strong with forelegs straight.				
HIND LEGS nearly perpendicular from hock to pastern. When viewed from behind, legs wide apart and nearly straight. Bone, flat and flinty, tendons well defined. Pasterns, of medium length, strong and springy. Hocks cleanly moulded.	8			
FEET short and well rounded, with deep heel and level sole.	—			
2. DAIRY CHARACTER		20		
Animation, angularity, general openness, and freedom from excess tissue, giving due regard to period of lactation.				
NECK long and lean, blending smoothly into shoulders and brisket; clean-cut throat and dewlap.				
WITHERS well defined and wedge-shaped with the dorsal processes of the vertebrae rising slightly above the shoulder blades.	20			
RIBS wide apart. Rib bone wide, flat and long.				
FLANK deep, arched and refined.				
THIGHS incurving to flat from the side; wide apart when viewed from the rear, providing sufficient room for the udder and its attachment.				
SKIN of medium thickness, loose, and pliable. Hair fine.	—			
3. BODY CAPACITY		20		
Relatively large in proportion to size of animal, providing ample digestive capacity, strength, and vigor.	12			
BARREL deep, strongly supported, ribs wide apart and well sprung; depth and width tending to increase toward rear of barrel.	—			
HEARTGIRTH large, resulting from long, well sprung foreribs, wide chest floor between front legs, and fullness at the point of elbow.	8			
	—			
4. MAMMARY SYSTEM		30		
A capacious, strongly attached, well carried udder of good quality, indicating heavy production and a long period of usefulness.				
UDDER—CAPACITY and SHAPE, long, wide, and of moderate depth. Extending well forward, strongly attached, reasonably level floor. Rear attachment, high and wide. Quarters evenly balanced and symmetrical.	25			
TEXTURE soft, pliable, and elastic. Well collapsed after milking.				
TEATS uniform, of convenient length and size, cylindrical in shape, free from obstructions, well apart and squarely placed, plumb.	—			
MAMMARY VEINS long, tortuous, prominent and branching, with numerous large wells. Veins on udder numerous and clearly defined.	5			
TOTAL		100		

AYRSHIRE CHARACTERISTICS

Color—Red of any shade, mahogany brown or these with white, or white, each color clearly defined. Distinctive red and white markings preferable; black or brindle markings strongly objectionable.

Size—A mature cow in milk should weigh about 1,150 pounds.

Horns—Inclining upward, small at base, refined, medium length, and tapering toward tips.

BROWN SWISS CHARACTERISTICS

Strong and vigorous. Size and ruggedness with quality desired. Extreme refinement undesirable.

Color—A shade of brown varying from a silver to a dark brown. Hair inside ears is a lighter color than body. Nose and tongue black, with a light colored band stretching around nose. Color markings which bar registry are: white switch, white on sides, top, head or neck, and legs above knees or hocks. White on belly or lower legs objectionable.

Size—A mature cow in milk should weigh about 1,400 pounds.

Horns—Inclining forward and slightly up. Moderately small at base, medium length, tapering toward black tips.

GUERNSEY CHARACTERISTICS

Color—A shade of fawn with white markings clearly defined, black or brindle markings objectionable. Skin should show golden yellow pigmentation. When other points are equal, a clear buff muzzle will be favored over a smoky or black muzzle.

Size—A mature cow in milk should weigh about 1,100 pounds.

Horns—Inclining forward, small and yellow at base, refined, medium in length, and tapering toward tips.

HOLSTEIN CHARACTERISTICS

Color—Black and white markings clearly defined. Color markings which bar registry are: solid black, solid white, black in switch, black belly, black encircling leg touching hoof, black from hoof to knee or hock, black and white intermixed to give color other than distinct black and white.

Size—A mature cow in milk should weigh about 1,500 pounds.

Horns—Inclining forward, incurving, small at base, refined, medium length, and tapering toward tips.

JERSEY CHARACTERISTICS

Color—A shade of fawn, with or without white markings.

Size—A mature cow in milk should weigh about 1,000 pounds.

Horns—Inclining forward, incurving, small at base, refined, medium length and tapering toward tips.

Dairy conformation. The term *dairy conformation* signifies that appearance which indicates a tendency to produce milk rather than to produce beef. It is generally characterized by angularity leading to the presentation of three wedges when viewed from the side, front, and top.

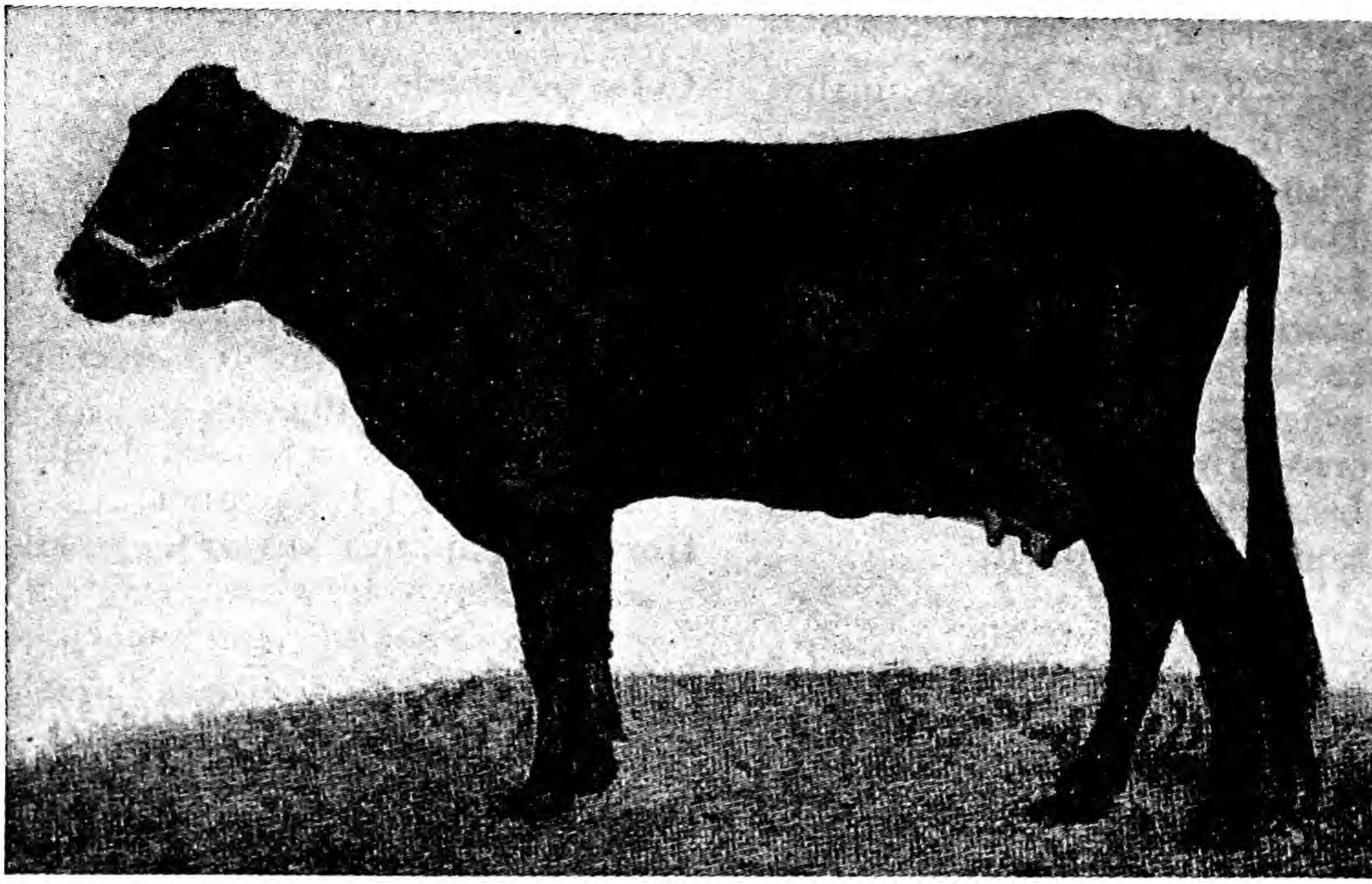


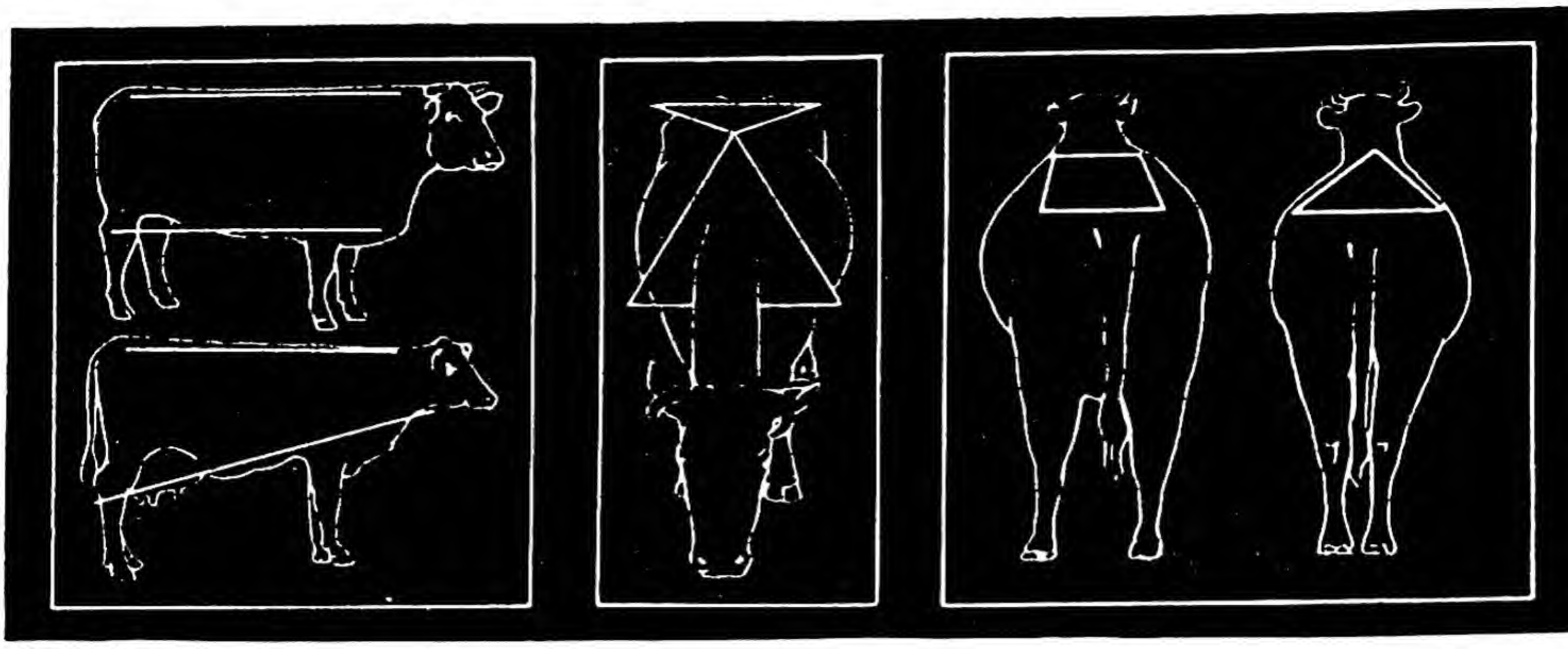
Fig. 43. Poor dairy type. A cow of nondescript breeding lacking in all the essentials for economic production. Cows of this type may be safely eliminated without testing.

The top and bottom lines, if extended, will meet in front of the head to form a wedge. When viewed from the front, the two lines over the shoulders form a wedge, with the apex at the withers. The third wedge is formed by the lines drawn from the hook bones to the withers, with the apex at the withers. For the ideal beef animal, these lines are parallel. (Fig. 44.) The difference in the conformation of dairy and beef types is due to differences in fleshing, as the skeletons of the two are essentially the same. (Fig. 45.)

In addition to the three wedges, all parts should be clean-cut and free from excess fleshing. The head and face should be clean-cut and feminine in appearance; the neck should be long, slender, and neatly joined with both head and shoulders. The shoulders should be free from coarseness. The back, hook bones, and pinbones should be prominent yet free from coarseness. The legs likewise should be clean-cut and free from coarseness, with clean-cut and preferably incurving thighs.

The cow should also be active in disposition, indicating capacity for work. Sluggish animals are seldom good feeders. Too nervous and easily excitable animals are undesirable because of difficulty in handling them and also because a large amount of energy is wasted in unnecessary excitement.

Well fed dry cows frequently acquire sufficient flesh to assume more of the lines of the beef cow. Undernourished beef cows may also lose enough flesh to assume somewhat the angularity of the typical dairy type. In these



Lamaster

Fig. 44. The top and bottom lines, the side lines, and the lines over the withers tend to form wedges on the dairy type, while the same lines are parallel on the beef types.

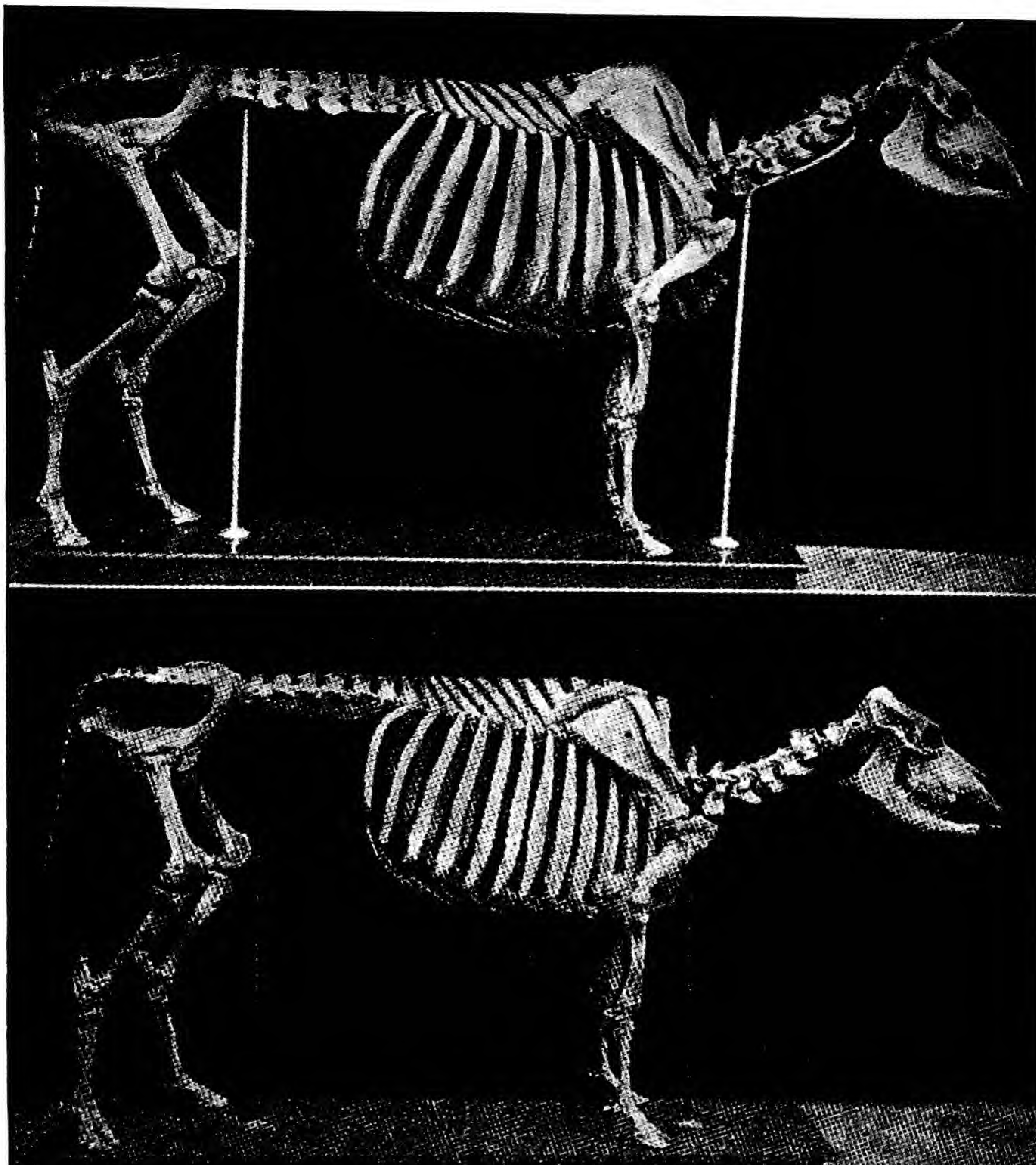
cases there are other characteristics that must be watched for. The size and shape of the udder and the difference in spring of ribs help differentiate between dairy and beef types. The ribs come out at more nearly right angles from the vertebrae on the beef animal than on the dairy animal.

Constitution and vigor. The high producing dairy cow performs an enormous amount of work in the mastication and metabolism of the large amount of feed that she must consume for the needs of milk production and body maintenance. It is, therefore, essential that she possess a strong constitution and much vigor. Strong constitution and vigor are indicated by the general healthy appearance of the animal and to some extent by certain anatomical features. The clean, alert eye, large nostrils, and large chest are the most significant. Size of chest—and, therefore, increased room for heart and lungs—is secured by depth, width of the chest floor, and spring of the foreribs. A long body also increases chest capacity.

Feed capacity. Cows vary greatly in the capacity for feed consumption. To some extent the ability to handle feed is indicated by body conformation. Animals with very shallow and narrow barrels are seldom capable of handling much feed. Sometimes animals with deep, wide, and long barrels do not possess the ability to consume large quantities of feed, but as a rule they are superior to those of smaller proportions.

In addition to large middles, large capacity for feed is indicated by a large muzzle and a soft, loose skin.

Mammary development. The extent of the mammary development is the most significant anatomical feature in predicting the producing capacity of a cow. More weight is given to this than to any other major feature listed on the score card. While the mammary development is the most reliable indication of the milk-producing ability of a cow, it is not infallible. Many cows with excellent udder development have been known



Reproduced from Swett and Miller

Fig. 45. Showing the similarities between the skeletons of beef and dairy types. The upper is that of Sophie 19th of Hood Farm, a highly specialized dairy cow of the Jersey breed, while the lower is that of Blackbird of Dallas, a purebred Angus and highly specialized beef cow.

to be poor producers; they are undoubtedly lacking in the inheritance of the hormones that stimulate the glands into continued activity.

The mammary development includes the udder, teats, and milk veins. The size, quality, and shape of the udder are important considerations. The udder must be large enough to make and hold the milk that is produced; cows with small udders cannot be high producers. Next to size, the quality of the udder is important. The udder consists of glandular secreting tissue, ducts, storage reservoirs, and connective tissue. The connective tissue tends to give the udder a hard texture, while the ducts and reservoirs produce a soft texture. Large udders consisting largely of

connective tissue are hard to the touch and of poor quality. Such udders are not capable of producing large amounts of milk. Good quality udders "collapse" following milking, while poor quality udders change but little either in shape or texture following the removal of milk. Udders or parts of udders that have been severely infected with mastitis develop large lumps. This is due to the secretory tissue being replaced by hard connective tissue.

The shape of the udder is important for three reasons. The correctly shaped udder has greater capacity than many of the poorly shaped types. A properly shaped and attached udder is not so subject to injury from various causes as a pendulous type, and the correctly shaped udder adds greatly to the beauty of the animal.

The desirably shaped udder is long and wide, and has a level udder floor. When both the fore and rear attachments are strong, this type of udder will have the greatest capacity and refrain from breaking down to become pendulous.

For convenience in milking, the teats should be of convenient size and placed squarely on the udder. Large tortuous milk veins extending far forward and entering the chest cavity through large milk wells are considered indications of good producing ability. Nearly all high producing cows possess these qualities, but not all cows with the desirable veining are capable of high production.

Defects in shapes of udders. There are many types of defects in the shapes of udders. The more common of these defects are illustrated in Figure 46.

An udder that is lacking in size and quality, regardless of shape, is to be avoided, notwithstanding what other qualities the animal may possess; for it is impossible to obtain much milk from a small udder lacking in quality.

The pendulous udder should also be avoided, since such udders are subject to injuries. A pendulous udder may receive bruises from objects over which the cow may pass, from striking the legs in walking or running, from being stepped on in arising, and in various other ways. These injuries not only result in inconvenience in milking but may also be the predisposing factor for mastitis, a disease that causes great financial loss to dairymen.

Funnel shaped, quartered, and unbalanced udders not only detract from the appearance of the cow, but such udders do not possess the capacities they would have if these defects were not present.

General appearance. *Breed type.* Conformity to breed characteristics, symmetry of form, and beauty come under this heading. These are not essential for high production, for many great producers have lacked materially in these qualities; but high production and beauty of form may be combined, as shown by the fact that many of the high producers have also been show ring winners. (Fig. 47.)

Symmetrical blending of all the parts. Straight and strong top lines, long, level, and wide rump, a square tail setting, straight legs, erect carriage, and stylish appearance are important considerations in the symmetrical

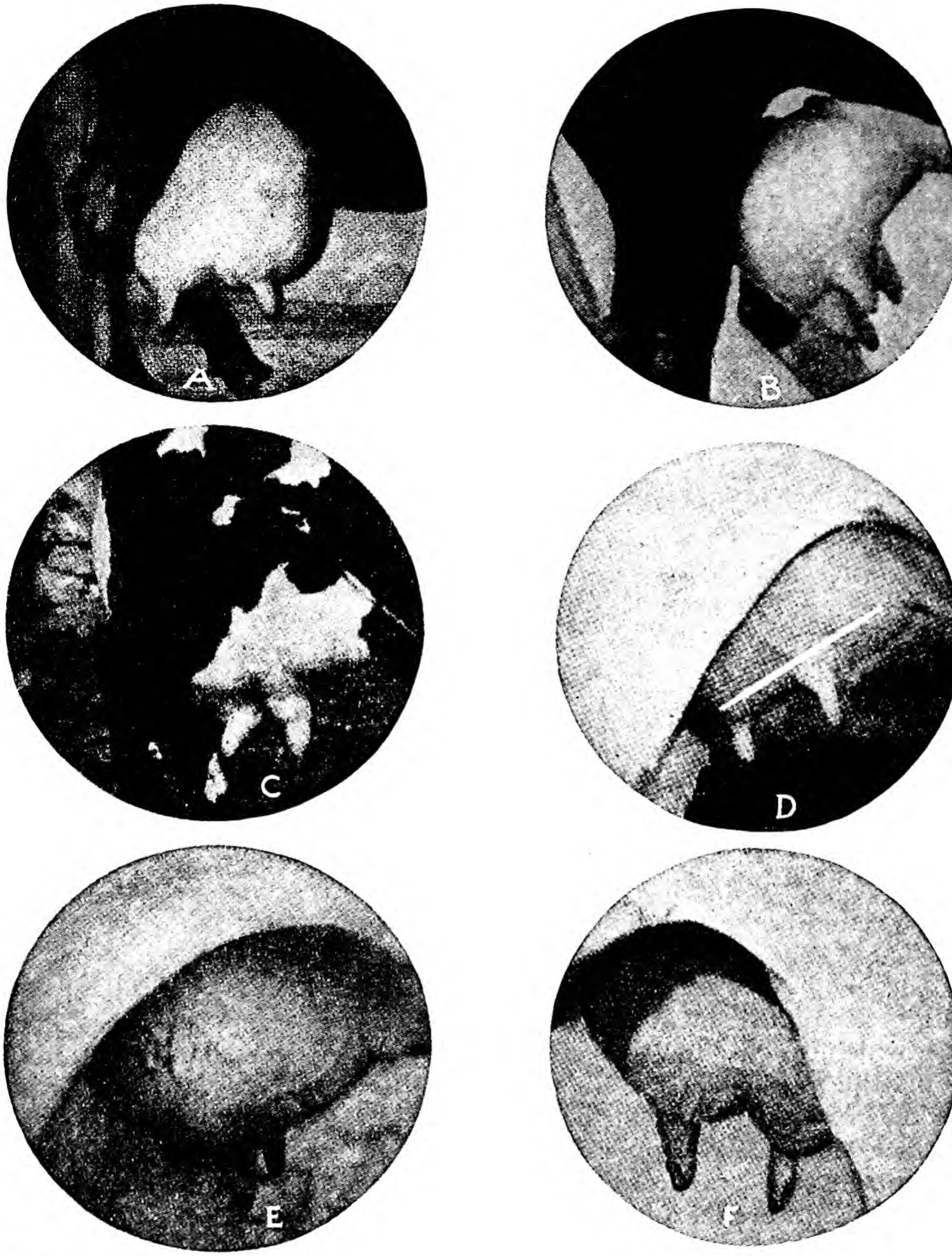


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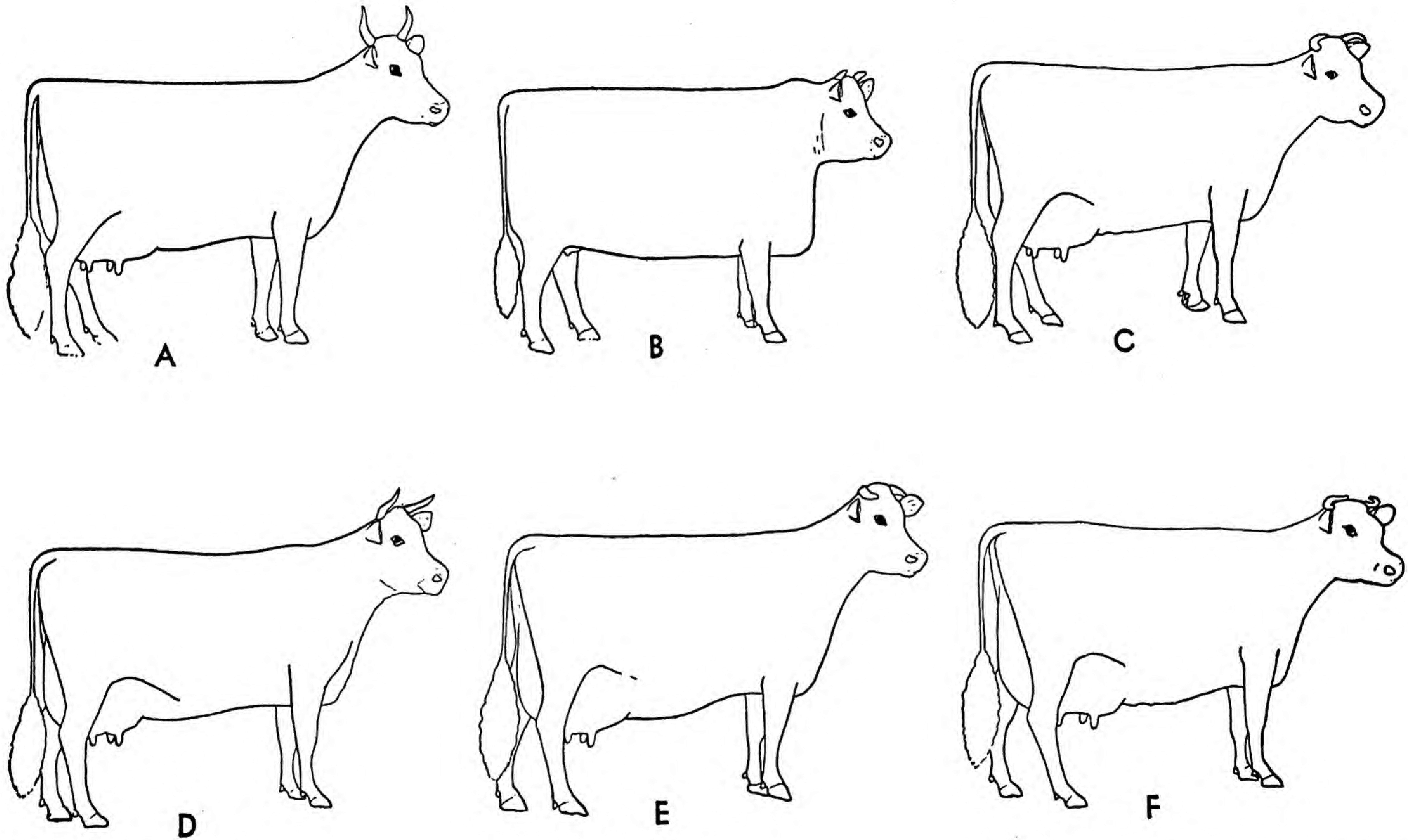
Fig. 46. Poor types of udders. Good shapes of udders are seen in Fig. 47. *A,* Pendulous udders. This is caused by a breaking away of the attachments, causing the udder to lower. *B,* Funnel shaped udder. This type gets its name from the fact that it tapers to a point like a funnel. *C,* Udder with good rear and fore development but teats poorly placed and of undesirable shape. *D,* Udder lacking in development of forequarters, the most common deficiency of udders. *E,* Unbalanced udder, with rear quarters lacking in development. *F,* Quartered udder.



N. N. Allen

Fig. 47. Outline of the true type of each of the five dairy breeds compared with that of a beef cow. Note the similarity of outline of the different breeds. *A*, Ayrshire; *B*, Beef Shorthorn; *C*, Guernsey; *D*, Brown Swiss; *E*, Holstein; *F*, Jersey.

blending of all the parts. For special breed requirements, see the score cards given at the ends of the chapters treating of the various breeds.

Dairy heifers. Type is not so reliable or satisfactory a basis for selecting young heifers as it is for selecting older and mature cows. Many changes take place in the conformation of animals with growth, and these changes may be for improvement or otherwise. The different body parts of the young animal have quite different proportions from those of the mature animal, and this fact must be taken into consideration when such an animal is evaluated. The legs are proportionately longer, the body more narrow and shallow, and the mammary development rudimentary. (See Chapter 28, "Growth and Development.") After making allowance for body proportions for the age, the same points are desired in the heifer as for the mature animal. Allowance should also be made for more fleshing in young stock than is tolerated in mature milking cows.

Many people believe there is good correlation between the degree of mammary development of the heifer and milk production when mature. It is also commonly believed that the placement of teats and the shape of the udder on the heifer are good indications of the shape of the udder when mature. While there is little experimental evidence available pertaining to these points, the validity of either one is to be questioned. The udder of the heifer consists almost entirely of fatty and connective tissues into which the glandular tissue develops. (See Chapter 31, "The Cow's Udder—Its Structure and Development.") The shape of the developed udder is dependent upon the direction the growth of the ducts and glandular tissue takes.

The extent of the glandular development in each of the four quarters in the growing heifers probably is a fair criterion of the size the udder will ultimately attain, but not of its shape. The glandular tissue can be palpated as more or less solid masses extending upward from each teat.

Chapter 21

FUNDAMENTAL CONSIDERATIONS OF HEREDITY

IMPORTANCE OF HEREDITY

THE AMOUNT OF MILK AND FAT A COW PRODUCES IS DEPENDENT upon two groups of factors: (1) inherited capacity for production, and (2) the environmental factors, such as feed and care. While a good cow may be fed and cared for in such a way that she will produce poorly, no amount of feed or care will make a high producer out of a cow which lacks the proper hereditary factors for a high production.

All the known hereditary factors behave according to definite laws. The science which deals with these laws and heredity in general is known as genetics. To properly understand the inheritance of any character or group of characters one must become familiar with certain fundamental considerations, which may be divided into two groups: namely, those which deal with the physical basis of inheritance, and those which deal with the laws governing inheritance. A knowledge of these fundamental considerations will help materially in understanding the problems encountered in the breeding of dairy cattle.

PHYSICAL BASIS

The body cell. The cell is the structural unit of all body tissues. It is microscopic in size, and differs in shape and composition in the various tissues of the body. The structure is complicated, but only one of the component parts, the nucleus, will be discussed here.

Since the nucleus contains all the factors involved in inheritance, a knowledge of the structure of the nucleus and its component parts is pertinent to this discussion. All cells capable of reproducing themselves are alike in that each possesses a nucleus that in turn governs the reproduction of cells. (Unnucleated cells, like the red blood cells and certain white blood cells, originate from nucleated cells.)

The nucleus of the cell in the bovine is exceedingly small, yet it is made up of a number of complicated structures. The structures that we are concerned with from the standpoint of inheritance are known as chromosomes. These carry all the hereditary factors. In all body cells the chromosomes are found in pairs. For a cow it is now believed that there are 30 pairs of chromosomes, one of each pair originating from the sire and the other from the dam. Each chromosome is further divided into parts known as genes. The gene is the unit of heredity; each gene is responsible for a character or part of one or more characters. (Fig. 48.)

Sex cells. Early in the embryological development certain cells are differentiated from the rest of the body for reproduction. For the male

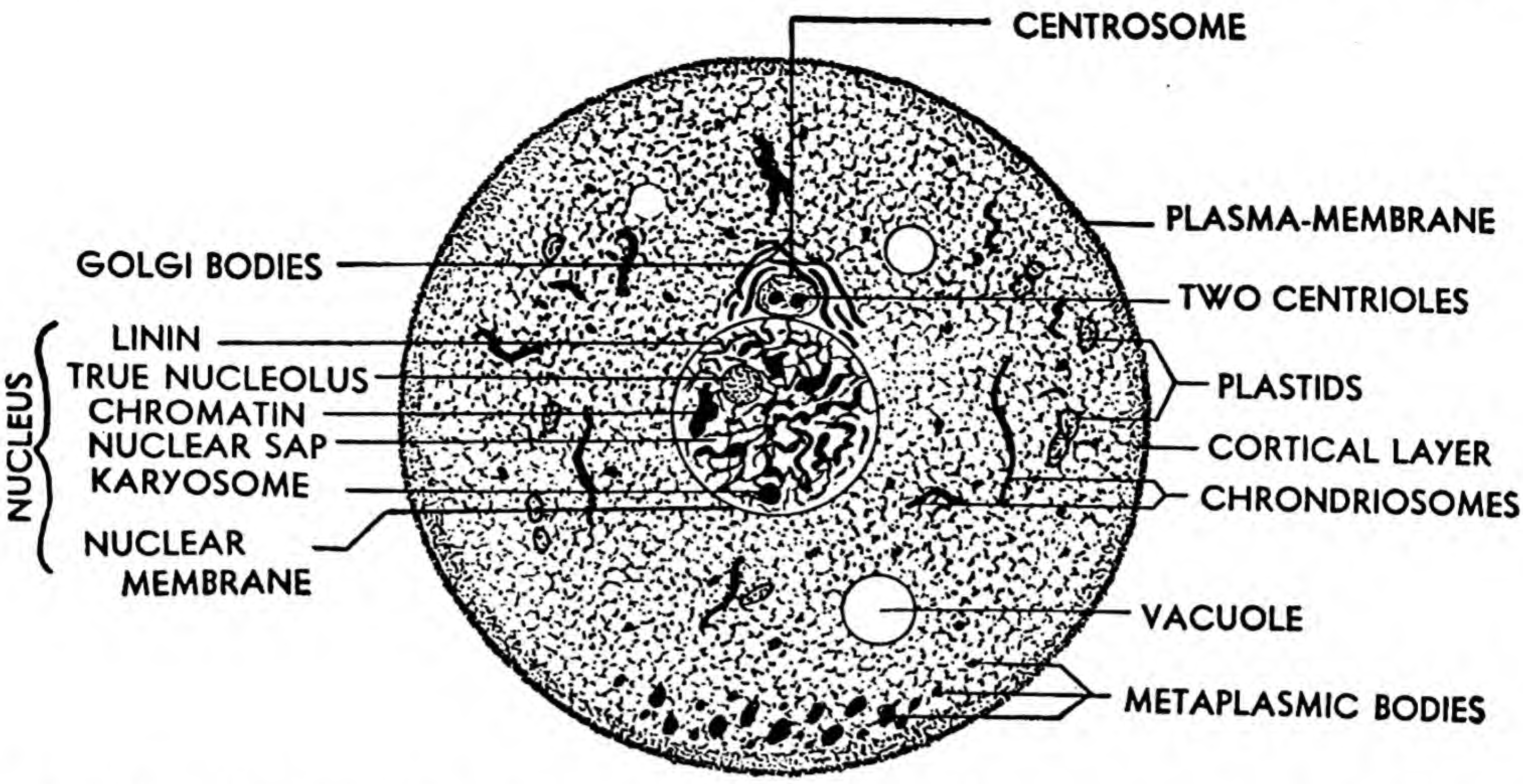


Fig. 48. A schematic representation of the body cell. Attention is called to its complexity and the fact that the factors for heredity are located in the nucleus.

they come to be located in the testes, and for the female in the ovaries. These cells are like other body cells in that they are nucleated and have chromosomes in pairs. In the process of maturing, however, two important physiological changes take place in the development of the sex cells. One is an increase in the number of the reproductive cells, and the other is a process of reducing the number of chromosomes from the paired condition to the single condition in which they are found in the mature sex cell or *gamete*, as it is commonly referred to in genetics. The process in the female is known as oögenesis, and in the male as spermatogenesis.

Oögenesis. Oögenesis is illustrated by diagram in Figure 49. An important point in this process is the reduction in the chromosome numbers, effected by casting off half of the chromosome in what is known as a polar body. In the casting off of these chromosomes the chances are even as to which one of a pair of chromosomes will be retained and which will be cast off.

Spermatogenesis. The mature male gamete is like the egg in that it has the chromosome in the single condition rather than the double condition found in the body cells. The process, illustrated in Figure 49, differs from oögenesis in that in the last stage the reduction of chromosome numbers is effected by dividing to form two male gametes, each one getting one of each pair of chromosomes.

Fertilization. The union of the male gamete and the female gamete is known as fertilization, and the resulting body from the union is known as a zygote. The zygote differs from either one of the gametes by having the chromosomes in pairs, one of each pair coming from the female, and one from the male. Neither of the gametes has the power of multiplying, but the zygote has this power, and cell multiplication goes on rapidly

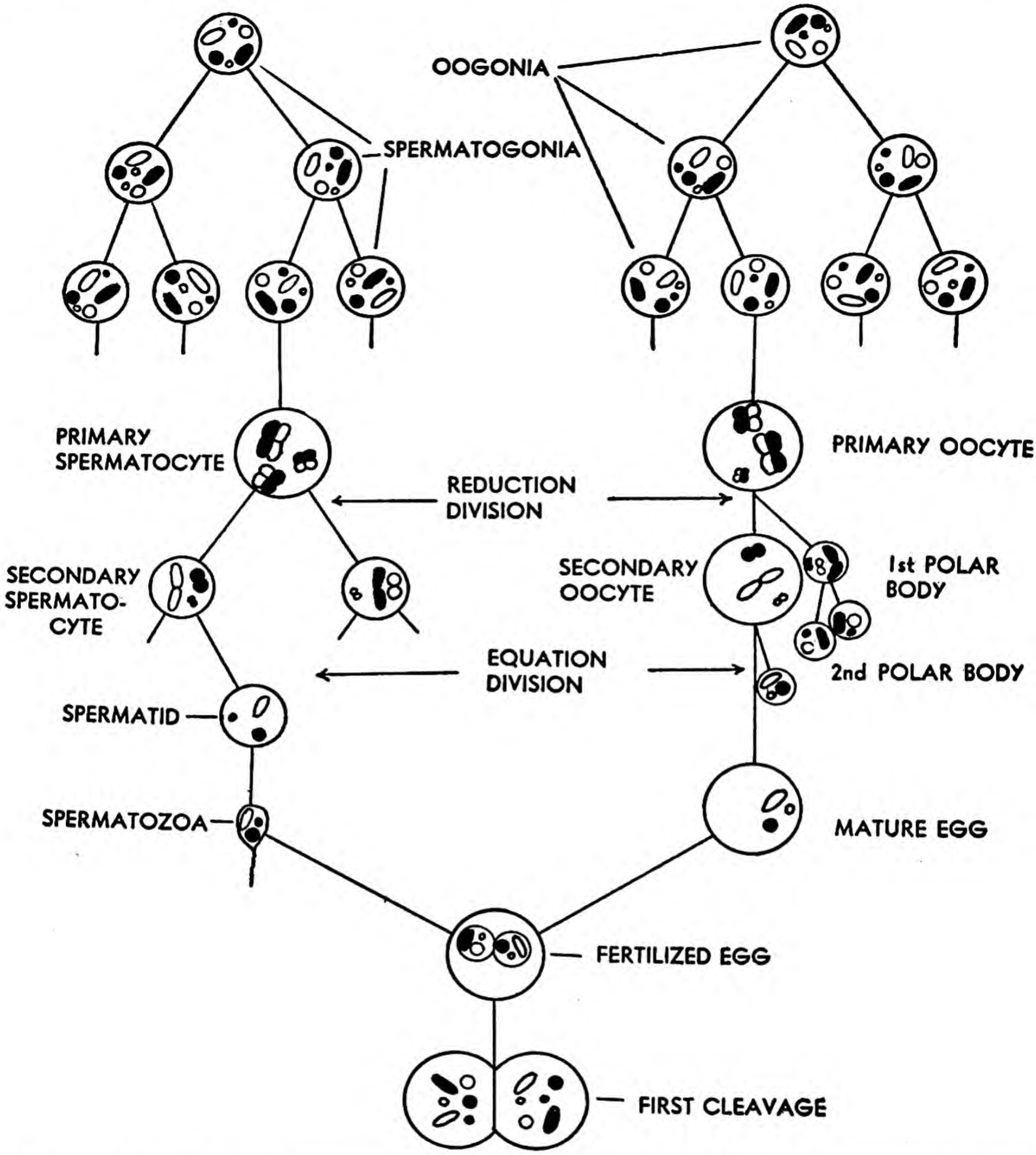


Fig. 49. A schematic representation of oögenesis (*right*) and spermatogenesis (*left*), together with fertilization and the first cleavage.

when it is implanted in the endometrium of the uterus. The zygote first divides to form two cells; these divide in two for the four cell stage, the four cells for the eight cell, the eight cells for the sixteen, and so on. In each division the chromosomes divide first, so that all new cells have the same chromosome numbers as the parent cell.

Summary. Briefly recapitulating the chief factors for the basis of heredity we have:

1. Body cells capable of dividing or producing other cells have a nucleus containing chromosomes that are paired.

2. The chromosomes carry hereditary factors in the genes of which they are composed.
3. The sex cells or male and female gametes are the result of a process in which the chromosome numbers are reduced to one-half of that which is typical for the body cells.
4. In fertilization the male and female gametes unite to form one cell, the zygote, in which the chromosomes are again present in pairs. One of each pair of chromosomes comes from the male parent and one from the female.
5. The zygote divides and redivides until a new individual is formed and the cycle begins over again.

LAWS GOVERNING INHERITANCE

The Mendelian Inheritance or Mendelism. The first experimental work on inheritance was conducted by Gregor Mendel, an Austrian monk who studied the inheritance of seven different characters in peas. The term *Mendelian Inheritance*, commonly used in genetics, gets its name from Mendel. While his work was published in 1866, no attention was paid to it until 1900 when his laws were rediscovered by a number of men. Genetics as a science, therefore, dates from the year 1900. A number of the fundamental principles of inheritance that Mendel advanced still hold. Some have been modified as new discoveries have been made. To understand the nature of inheritance one must become familiar with these fundamental principles, a discussion of which is given in the following paragraphs.

Dominance, recessiveness, and epistasis. When a gene expresses itself and completely prevents the expression of its allelomorph, it is said to be *dominant*, and the gene that it is dominant to is said to be *recessive*. If a gene expresses itself completely over another gene located in a different position in the chromosome or in some other chromosome it is said to be *epistatic*. The difference between epistasis and dominance is not always recognized. Black is usually said to be dominant to red when more probably it is epistatic to red.

While Mendel claimed that all characters behave as dominant and recessive, there may be partial dominance or intermediate inheritance or even cumulative inheritance. There is no positive intermediate inheritance in cattle. In plants, however, this type of inheritance is quite common. A red snapdragon crossed with an ivory snapdragon produces F_1s (the first filial generation) that has pink flowers. Cumulative or blending inheritance is that type of inheritance in which each of the allelomorphic genes contribute a portion toward the expression of a character. Some people believe that this type of inheritance is important in milk production.

Unit character. Mendel believed that each character was the expression of a single factor, but it is now known that, in the main, from several to many factors or genes are required for the expression of a single character. Apparently the character "Self" (solid color) is due to but one gene, but to produce the color pattern of the Holstein several genes are needed.

The inheritance of milk production may require a score or more genes, as is also the case with size, vigor, and a number of other much desired characters.

Illustration of inheritance. Most of the fundamental laws of inheritance can be illustrated in a cross of Holsteins and Red Polls for two generations. The Holstein is black with white spotting and has horns; the Red Poll is of solid color, red, and hornless. All F_1s, or first filial generation, are hornless, solid colored, and black. If the F_1s are crossed among themselves to produce the F_2s, or second generation, it takes 64 animals, on the average, to bring out all the possible genetic combinations of these three characters. These will be distributed as follows:

27 black, solid color, and hornless
9 black, solid color, and horned
9 black, spotted, and hornless
9 red, solid color, and hornless
3 black, spotted, and horned
3 red, solid color, and horned
3 red, spotted, and hornless
1 red, spotted, and horned

From Figure 50 it will be noted that the F_1s are all black, hornless, and of solid color. The solid color of the Red Poll is dominant to the white spotting of the Holstein, the black of the Holstein is epistatic to the red of the Red Poll, and the hornless condition of the Red Poll is epistatic to the horned condition of the Holstein.

Homozygous and heterozygous. When both members of a pair of genes are alike, the condition is known as homozygous; and if they are different, it is said to be heterozygous. The principle of this may be illustrated for the characters horned and hornlessness by letting HH represent the hornless condition in the Red Poll, and hh, the horned condition in the Holstein. Each parent can produce but one type of gamete as far as this character is concerned. For the Red Poll each gamete would have the H, and for the Holstein each one would have the h. The F_1s are heterozygous for horns (Hh), but because hornlessness is dominant to the horned condition, all individuals are like the hornless parent in this particular.

Variation. The hope for improvement of livestock by breeding lies in the fact that there is much variation. While the Holstein and the Red Poll are homozygous for the respective characters of white, spotting, horns, black, hornlessness, red, and solid color, they are variable for many of their other characters. The general law governing variations is illustrated in Figure 50, which gives the F_2 generation distribution where from two parents appearing alike eight different types of offspring are produced. The factors for milk production are probably more variable in the dairy breeds than the factors for these sample characters illustrated in the Holstein-Red Poll cross. The object of a breeder is to select for homozygosity of the desirable characters and thereby eliminate variation.

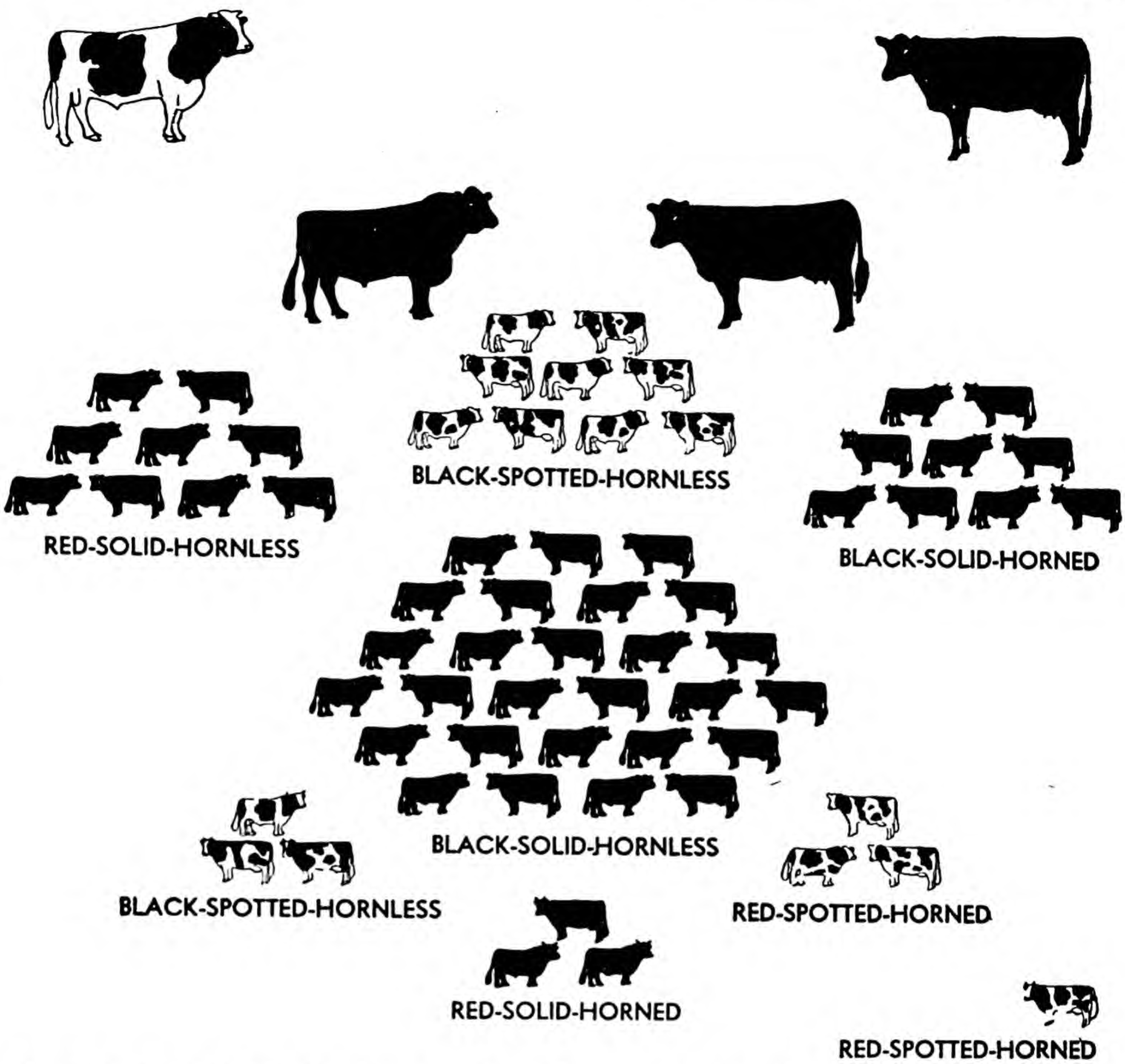


Fig. 50. Trihybrid inheritance. The offspring possess the dominant characters of the parents. Offspring from Holstein x Red Polled are hornless, black, and solid of color. Their offspring (F_2), however, will be of eight different types, in which all the characters of the grandparents (P_1) will appear and in new combinations. On the average, 64 individuals are needed to bring out the types.

Genotype and phenotype. In order to facilitate discussion it is necessary to know these two terms and what they represent. Phenotype refers to the characteristics of an animal that can be seen; genotype refers to the genetic composition of the animal, part of which is expressed in the phenotype. The phenotype for the three characters, horns, black, and spotted condition, in the Holstein is the same as the genotype. In the F_1 generation of the Holstein-Red Poll cross, however, both the genotype and the phenotype contain the recessive for these three characters. The genotype of an individual can be determined only through the characteristics observed in the offspring. This fundamental conception can be put to practical use in studying the genotype of the breeding animals.

Hybrid and hybrid ratios. Hybrid refers to heterozygous individuals and is commonly used to designate animals from parents of different breeds. A monohybrid is one with only one factor difference, such as horns and hornlessness. When one factor is based upon dominance and recessiveness, it takes an average of four individuals to bring out all of the two types that will result. A cross of the F_1s with each other produces horns to the hornless condition in the ration of 3 to 1. Of these, one is homozygous for hornlessness, two are heterozygous, and therefore hornless, and one is homozygous for horns.

A dihybrid is one in which two factor pairs are involved. Here it takes 16 individuals to bring out the four types, one of which will be double recessive for both factor pairs. Crossing a red hornless individual with a black horned individual, there will be:

9 black and hornless (one of which is homozygous for both pairs of factors)
3 black and horned
3 red and hornless
1 red and horned

A trihybrid ratio has been illustrated in the consideration of the three sets of allelomorphs in the Holstein-Red Poll cross. With an increasing number of factors involved the complexity increases in geometric proportions. For four factor differences it requires, on the average, 256 individuals to get out all possible combinations. Some believe that as many as 18 factor pairs are involved in the inheritance of milk and butterfat production; in that case, the possibility of an infinite number of recombinations exists.

Linkage. Linkage in inheritance exists when one gene goes with another one in the same chromosome. If genes are linked, the characters for which such genes are responsible appear together. In cattle only one linkage of characters is now known and that is in connection with the white heifer disease, a case of sterility which is associated with the inheritance of white color. In plants many linkages are known, and advantages are taken of this information in breeding. In human beings color blindness and hemophilia are each linked with sex. The linking of characters in dairy cattle might be very helpful in the breeding program.

Acquired characters. It has been commonly believed by the laity that inheritable characters could be acquired; thus, for example, pregnant mares were trotted on the race track in order to insure racing ability to the colt. Extensive experimentation, however, has shown that characters cannot be acquired in that way. The germ plasm is set aside from the somatoplasm or body cells and is not dependent on it or influenced by it. The docking of the tails of sheep has been done for many generations without affecting the inheritance of that part of the anatomy.

Mutations. To what extent mutations have played a part in the inheritance of cattle is not known. Undoubtedly there are many cases where the inheritance has been influenced by mutations of one kind or another.

There are several cases on record of albino cattle, the appearance of which can best be explained by a mutation of the chromosomes or of the genes carrying the color factor. Hornlessness also is a mutation and has come in spontaneously in herds that were horned. Very little is definitely known about the effects of mutation on the important practical character of dairy cattle.

With an understanding of these fundamental principles concerning the physical basis for inheritance and these general laws governing the nature of inheritance one will be better able to understand the reasons for the observed differences in cattle and why apparently new types can spring from old ones.

Chapter 22

MEASURES OF THE GENETIC MAKEUP

THE OLD ADAGE THAT LIKE BEGETS LIKE IS ONLY PARTIALLY TRUE. IT IS common knowledge that characters may appear in the offspring that were not apparent in either one of the parents. The red and white Holstein from black and white parents and the horned offspring from hornless parents are examples of this phenomenon. While not much is definitely known about the inheritance of the capacity to produce milk, except that there are many factors involved, it is apparent that here, too, the offspring may vary widely from the production capacity of the dam and the calculated production level of the sire. The offspring may be inferior or superior to either or both of the parents. In the light of modern genetics such behavior can be explained on the basis of a heterozygous condition of the parents, permitting a recombination of factors in the offspring. Such recombination of many factors may account for wide ranges of variations. This can be illustrated by considering three of the many factor pairs involved in the inheritance of the capacity to produce milk, making the following assumptions:

1. The genes are dominant and recessive.
2. A, B, C represent the dominant genes, and a, b, c represent the corresponding recessive genes.
3. Each parent is heterozygous for two pairs of genes, and double recessive for one pair.
4. The double recessive condition is for a different pair of genes in the two parents.

The genetic makeup of the two parents for the three factor pairs is represented:

Aa	Aa
Bb	bb
cc	Cc

Each parent can produce four different gametes: ABc, Abc, aBc, and abc by one parent, and AbC, Abc, abC, and abc by the other. If the first gametes listed for each parent unite, the resulting individual will have the composition AA, Bb, Cc, or a higher production capacity than either parent. If the last gametes listed for the two parents unite, the resulting individual will have the composition aa, bb, cc, or a much lower production capacity than either parent.

The object of the breeder of dairy cattle is to produce animals that are homozygous for all the desirable characters; and to approach such an end he must know not only the phenotype but also the genotype of the

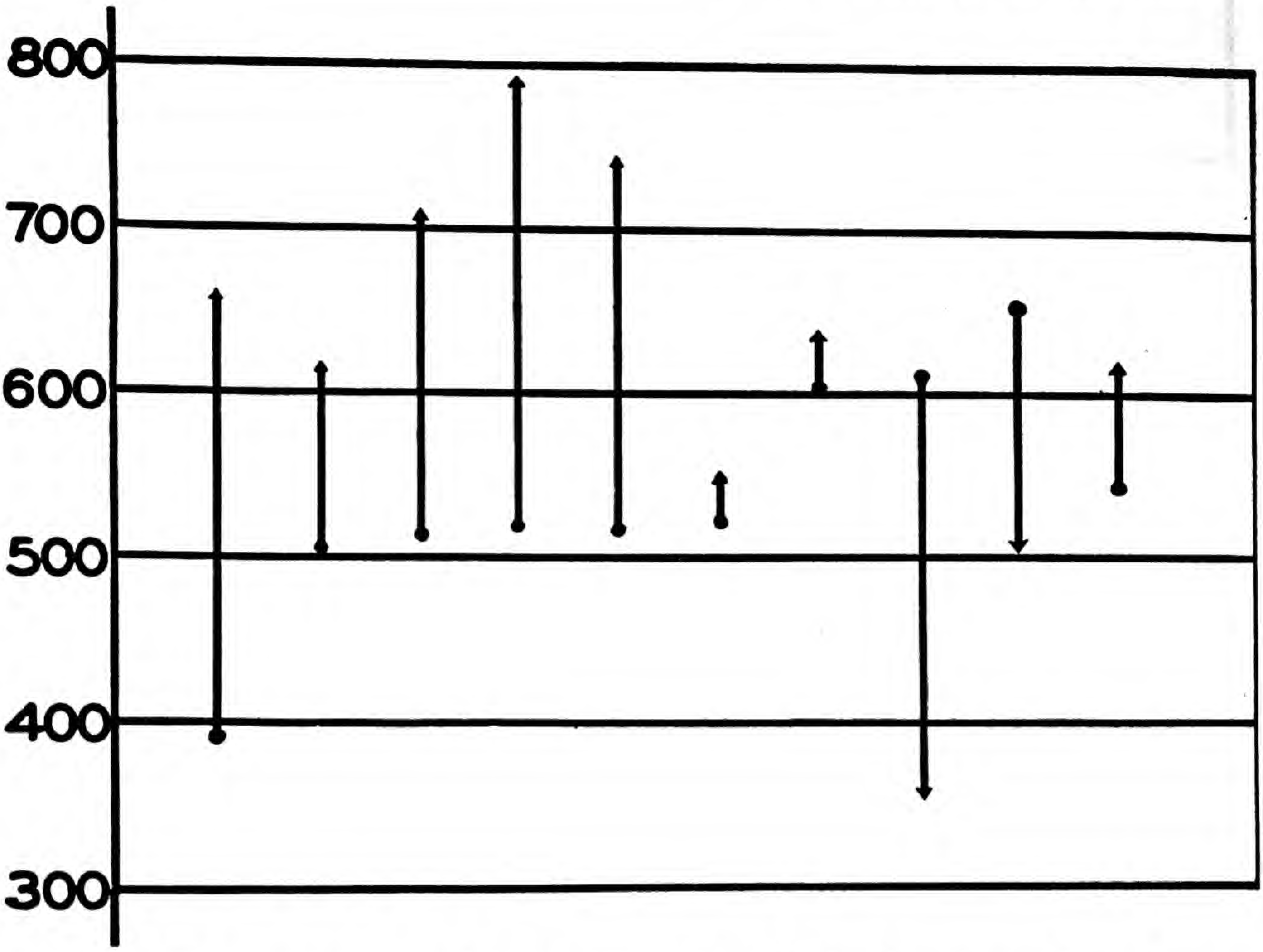


Fig. 51. This is an arrow chart, a convenient device for comparing the performance of the daughters of a bull with that of their dams.

breeding animals. The problem, therefore, is one of ascertaining the genotype; the measures for doing this are discussed in the following pages.

Production record of the dam. In the past the milk and butterfat record of the individual, if a cow, or of the individual's dam, if a heifer or a bull, has been the chief criterion in evaluating such an animal for breeding purposes. The milk or butterfat production record of a cow is a phenotypic character—the same as black and white color—and it does not necessarily represent the genetic makeup. As the black and white animal may possess factors for red, so the high milk production record cow may possess factors for low production. Because of this the offspring from high producing cows may be quite mediocre. A study of this phenomenon has given rise to a law, first propounded by Galton, which is known as the Law of Regression. This law shows that the tendency is for offspring from extreme parents to deviate from such parents toward the average of the population. Gowen, studying correlation between daughter and dam, found that the Law of Regression applies to the inheritance of milk production. This fact is illustrated in Figure 48. Due to the large number of animals involved the lines in this chart are straight. Depending upon the degree of heterozygosity present in the parents, individuals deviate markedly from the average. Special note should be made of the fact that for extremely high production, the daughters deviate more markedly from their dams than is

the case with lower production. This is accounted for by the probability that extremely high production is a result of a fortunate combination of factors coming from both the sire and the dam, and that such an individual would be more heterozygous than one with lower production records. While the selection of breeding stock from dams with high production records has aided materially in improving dairy cattle, it falls far short of accomplishing what might be accomplished through the use of better methods in evaluating the breeding stock on the basis of its genetic makeup.

Progeny test. The most reliable means of determining the genetic makeup of an animal is through the performance of the progeny of such an animal. If the progeny test is to be significant, two important considerations must be taken into account: first, the proper matings must be made; and second, there must be sufficient numbers of the progeny to bring out the factor combinations. Progeny from distantly related parents are not so reliable in indicating the genetic makeup of the parents as are progeny from parents of closer relationship. For the inheritance of a complex character like milk production, at least, distantly related parents are more likely to have factors for high production in different chromosomes, and these factors will have a tendency to dovetail or complement one another in such a way that the daughters will be higher milk producers than the dam, and also more heterozygous. Breeders have observed increased milk production from the crossing of certain strains, and refer to this phenomenon as "nicking." The geneticist recognizes the soundness of this hypothesis, and has applied the term "heterosis" to the phenomenon.

The effects of heterosis are recognized in crossbreeding, the offspring usually being much more vigorous than either one of the parents. It is, therefore, evident that mating distantly related parents may not be a test of the genetic makeup of these parents. High producing daughters from a cow may also owe their inheritance to the sire, who may be unusually prepotent; therefore, in order to properly evaluate the genetic makeup of a cow, something should be known about the sire, in regard to his inheritance for milk production. Furthermore, the records of daughters by different sires are of more significance than those of daughters from the same sire. Since the bull's daughters are usually out of different cows, there is no great danger of falling into this error in using the progeny to evaluate his genetic makeup, but the effect of heterosis is equally dangerous in confusing the evaluation of the genetic makeup of the sire. Undoubtedly when a bull has proved to be a sire of good production in one herd and fails in another, heterosis is the basis for the difference. The herd where he was recognized as a sire of high production had the genes for production that would complement or "nick" with the genes that he possessed and thus result in a factorial combination in the offspring for high milk production, while the other herd did not.

Backcrossing. Since the parents and other offspring are likely to have the same genes in common, a better test for the genetic makeup of an animal is to backcross; that is, to breed back the sons to their dams, or the

daughters to their sires. When so doing, there is one chance in four that a recessive gene present in both parents and offspring will manifest itself in the F_2s as a double recessive. Inasmuch as only every other one of the offspring will receive the recessive gene from a heterozygous parent, only one out of eight of the F_2s will have a double recessive and thus express a recessive character. Thus, if a Holstein bull is suspected of carrying a recessive gene for red and is backcrossed to his daughters, an average of one out of eight of the calves will be red and white. This emphasizes the need for sufficient number of offspring to prove the genetic makeup of any one animal. For a complex character such as milk production, where a large number of genes is required for the expression of the character, not so many progeny are needed to determine whether or not the animal is highly heterozygous. If the animal is highly heterozygous, the chances are that the F_2s will receive a number of recessive genes and will be inferior to the parents from the standpoint of milk production.

The ideal test. The ideal test for the genetic makeup of an animal would be the mating of such an animal to one that is double recessive for all the characters desired. Thus, to prove whether or not a Holstein carries the recessive red factor, a cross with a red animal would require only an average of two progeny to bring out that character. For a test of heterozygosity for milk production, securing a double recessive animal for the genes involved would be difficult. Undoubtedly, beef animals are lacking materially in factors for milk production; but in crossing a beef animal with a dairy animal other complications are introduced. The beef animal undoubtedly possesses large numbers of genes that are dominant and that are involved in the expression of the character "beefiness." In a cross with a dairy animal it seems reasonable to believe that there would be a conflict for expression between the genes for milk production and for beef production, and thus the resulting individual would be a test neither for the genetic makeup of the beef animal nor for that of the dairy animal. It would seem that the best test animal for the genetic makeup for milk production would be one within the same breed that lacks, in so far as can possibly be ascertained, genes for the expression of all the characters that go to make up milk production.

Limitations. Complete analysis of the genetic makeup of cattle is impossible because of the length of the reproduction cycle and the few numbers of offspring from a cow. By the time a record on the progeny from a cow could be obtained, the cow would be about six years of age. Also, the average of five offspring from a cow would be a good number. While a satisfactory number of daughters can be obtained from a bull, the results are partly obscured by the inability to secure the necessary information on the genetic makeup of the cows to which he is mated.

Pedigree. The pedigree in its original meaning is simply an extended record of the ancestry; in that sense any animal could have a pedigree. Among dairy cattle breeders, however, a pedigree is limited to the purebreds, and sometimes purebreds are referred to as pedigreed stock. Then too, the pedigrees, in addition to being mere tabulations of the ancestry,

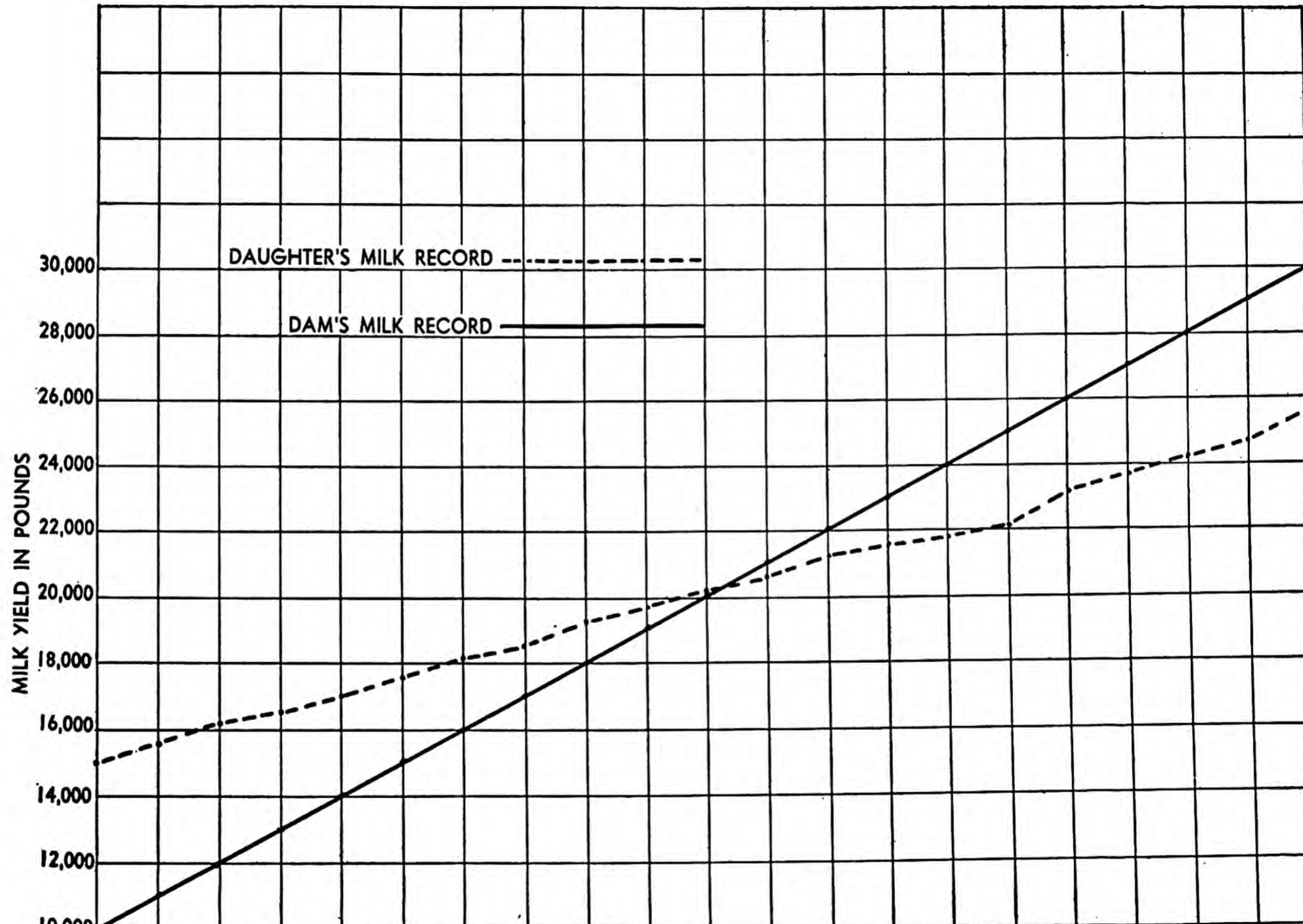


Fig. 52. Milk yield of dams and average yield of their daughters.

contain varying amounts of information about the individuals appearing in such tabulations. In most cases it contains the records of performance of the individual, if it is a cow, and the records of daughters of both bulls and cows. The writing of pedigrees has become quite a specialty, and a pedigree writer sometimes resorts to the use of phraseology that will connect the records of distant relatives more closely with an animal whose pedigree is being considered. The pedigree can be of great service in estimating the breeding value or genetic makeup of an individual. Most pedigrees, however, do not contain sufficient information to be of great value in this connection. The point can be best illustrated by discussing a pedigree as it should not be. Figure 49 is the reproduction of a pedigree which is worthless for evaluating that animal. It will be noted that while a considerable number of animals with records are listed under the sire, they are brought there by the phrase "by brother to the sire of." The animals listed under the sire are such distant relatives of the sire that they have no significance. Similarly, listing a number of animals with records under the dam is to be criticized, as they are "by a brother to the sire of the dam." Practically all of the listing of records in that pedigree can be criticized in the same way. This naturally leads to a discussion of the importance of the various generations in the pedigree.

It is apparent that the most important individuals in the pedigree are the parents, and that the next most important are the grandparents. Only 25 per cent of the genetic makeup of the individual comes from each grandparent. The important evidence, therefore, in the pedigree is that which will give information as to the general makeup of the parents and the grandparents. Here the records of the dam and the two grand dams are of some significance, but relatively small. Far more important evidence is the record of the daughters of the sire and the grand sires and of the dam and grand dams. If all the daughters have been tested and their records are uniformly good, and if there are sufficient numbers of such daughters, then the chances are very good that the individual has the same inheritance. Not only should the production records of the daughters be high, but they should be uniform. If one or more daughters of a bull or a cow have a low milk production record, that should be considered as positive evidence that such an animal has factors for low production; and if it has happened once, there is no assurance that the animal in question has not received the same inheritance.

In evaluating a pedigree, in addition to making sure that the offspring are of uniformly high production, care should be taken to ascertain that the animals listed in the pedigree have not been selected, so that a few of the highest producing offspring are listed while the rest are omitted. It is a rather common practice for pedigree writers to list the highest producing daughters and fail to mention those that have lower records. In addition to this, the breeder frequently selects the most likely cows for testing, leaving untested those that are not so promising. Thus, the information available is not representative of the actual facts.

One other precaution must be taken, and that is to ascertain the type

This youngster has splendid backing. His sire is from a 26 lb. 4 year old and by the 30 lb. bull who is by a brother to two 1,000 lb. cows and from a sister to the breed's greatest long distance sire, Sir Pietertje Ormsby Mercedes, who has 12 daughters that have produced over 1,000 lbs. of butter.

His dam is by a 20 lb. son of King Korndyke Colantha Ormsby, whose daughters are making splendid records in both short- and long-time tests. He is a full brother to a 34 lb. 4 year old with a 1,000 lb. year record.

SIRE

By a brother to the sire of:
Queen Piebe Mercedes. 4y 1389.45
30230 20
(World's Record for class)
Glen Canary De Kol 2d. 4y 1434.36
Milk 25590.20
Bess Pietertje Ormsby Merc. 1235.32
Milk 29053.20
Bess Burke Ormsby. 1146.01
Milk 26044.70
Dinah Pauline Clothilde Ormsby 4½y 1146.01
Milk 24078.10
Queen Piebe Ormsby Merc. 4½y 1136.01
Milk 24123.10
Miss Minita Ormsby Merc. 1078.07
4 others above 1,000 lbs.

DAM

By a brother to:
Miss Korndyke Johanna Rue 4y 30.65
Milk 605.10
Miss Korndyke Haidee Orms. 4½y 30.35
Milk 622.80
Queen Eagle Korndyke Heng. 4y 30.22

Sire is by a full brother to:
Miss Colantha Korndyke Orms. 4½y 34.08
30 days butter 131.40
365 " " 1089.43

GRAND SIRE

By a brother to:
Semi-official records
Miss Korndyke Maid Ormsby 1255.64
Milk 25418.30
Jenny Wren Korndyke Heng. 1050.48
4 from 30 to 39.56 lbs.

GRAND DAM

At 4 yrs., 5 mos.
Butter 26.11
Milk 475.00
At 3 yrs. 2 mos.
Butter 20.86
Milk 388.40
Butter, 30 das. 80.31
Milk 1617.30
At 2 yrs., 3 mos.
Butter 13.09
Butter 289 das. 364.43
Milk 8232.7

GRAND SIRE

By a brother to the sires or dams of:
Irma Johanna Concordia 4½y 37.93
Gypsy Lyons 33.63
Queen Lyons Gelsche Rosewood 33.31
Daisy Colantha Girl 4½y 31.81
9 others above 30 lb.

GRAND DAM

By a brother to:
Grace Fayne 2d's Homestead 35.55
(World's record when made)
Lady Oak 2d's De Kol
8y 34.14
7y 32.19
Jessie Fobes 2d's Maud Homestead 31.17
4 others above 30 lbs.

GREAT GRAND SIRE
6 A.R.O. Daughters
Willow Ridge Korndyke Capitola, 4½y 19.98
2 others above 332 lbs.

GREAT GRAND DAM
Butter 30.44
Milk 579.40
Butter, 30 das. 120.54
Butter, 365 das. 832.05
Milk 19028.30

GREAT GRAND SIRE
22 A.R.O. daughters
14 from 20 to 28 lbs.
3 above 594 lbs.
6 A.R. sons

GREAT GRAND DAM
Butter 19.02
Butter, 365 das. 484.15
3 A.R.O. daughters.
2 above 22 lbs.
1 A.R. son

GREAT GRAND SIRE
14 A.R.O. daughters
3 above 30 lbs.
4 others above 20 lbs.
3 above 521 lbs.

GREAT GRAND DAM
Butter 2½y 20.07
Milk 422.50
Sister to:
Eight from 20 to 27 lbs.

GREAT GRAND SIRE
34 A.R.O. daughters
7 from 20 to 23 lbs.
8 A.R. sons
14 producing daughters

GREAT GRAND DAM
Butter 3½y 17.49
Milk 445.20
Sister to:
Pearl Orms, Burke 30.56

Fig. 53. A poor pedigree. There is no information given in this pedigree that is of any value in evaluating the bull. By clever use of phraseology records of good producing but distant ancestors have been brought forward. None of the first two generations have any record of performance.

of management that has been used in making the records. If the animals have been forced and given the best of "Official Test" care, a higher production should be expected than if ordinary care has been given the animals while on test. Then, if all the information is available, if all the offspring of the parents of the two first generations have been tested, and if there are sufficient numbers of such offspring from each of the parents —say, three daughters from the cows and 20 daughters from the bull—analysis of the information given should give a reasonably accurate indication of what the probable production inheritance is of the animal in question. In addition to the listing of production records in the pedigree, the type of the individuals may be indicated by its show ring performance or by its type rating.

Bull index. In recent years several attempts have been made to evaluate the genetic makeup of a bull in the form of the so-called "Bull Index." The idea behind the bull index is that by considering the performance of the progeny and their dams, a figure can be arrived at that will be indicative of the milk production transmitting powers of a bull. In all, about ten such indexes have been proposed, each one varying in detail. The Mount Hope index, having been greatly publicized, is perhaps the best known. This is based upon the result of crossbreeding work conducted at the Maine Station. The index for milk and fat percentage is determined by the use of two different formulae. For the Mount Hope index, as well as all other bull indexes, the yearly milk record must be calculated to a mature equivalent. This also must be done with butterfat production.

Mount Hope index—milk. Compute the average mature equivalent of the milk production of all the daughters of a bull and also the average mature equivalent of the milk production of the dams of these daughters, and take the difference between these averages.

If the daughters' average exceed the dams' average, add three-sevenths (or .4286) of the difference to the daughters' average to get the bull's milk index figure.

If the daughters' average is less than the dams' average, subtract seven-thirds (or 2.333) of the difference from the daughters' average to get the bull's milk index figure.

Mount Hope index—butterfat per cent. The index for percentage of butterfat is obtained by similar operations, but with different fractions.

If the daughters' butterfat average percentage exceeds the dams' butterfat average percentage, add three-halves (or 1.5) of the difference to the daughters' average to get the bull's butterfat index.

If the daughters' average is less than the dams' average, subtract two-thirds (or .6667) of the difference from the daughters' average to get the bull's index.

The Holstein-Friesian Association index. The Holstein-Friesian Association calculates the bull index for all bulls having daughter-dam pairs with herd test records. The index is known as an "equal parent index" and is based upon the formula:

Bull's index = dams' average + 2 (daughters' average − dams' average)

The same formula is used for both milk production and fat percentage.

Gifford index. This index, which bears the name of its author, disregards the dams' production. The index is merely an arithmetical average of the daughters' records computed to a mature basis.

Criticisms of the bull index. By the use of the Mount Hope index, bulls have been found to have a negative index. In case of equal parent index this situation is possible but not so likely, as the daughters would have to average less than one-half the production of their dams in order to secure values less than zero. The values for the same bull may vary greatly, depending upon whether the Mount Hope, Holstein-Friesian, or the Gifford indexes are used. If the daughters are lower producers than their dams, the Mount Hope index gives the lowest values and the Gifford index the highest values. If the daughters' exceed the dams', these indexes arrange in a different order.

Aside from the Gifford index, all bull indexes are based upon the assumption that the production record of a cow is an accurate measure of her transmission ability. This is definitely not so, as has been shown previously. The high producing cows are likely to have a favorable combination of factors for high production which have small chances for transmission to the offspring.

Another assumption that lacks proof in its support is that of cumulative inheritance. Work done at the Minnesota Station and elsewhere has shown that the index secured for a bull upon a limited number of his daughters may be very materially different from the index for the same bull derived from another set of daughter-dam pairs. This is what would be expected upon consideration of the fundamentals of inheritance. If the factors responsible for milk production are dominant (and there are good reasons to believe that they are), then the Gifford index or the mere arithmetic average of the bull's daughters would be indicative of his potential level of production. Studies at the Minnesota Station seemed to support this. No correlation was found between the dam's records and the daughters' records from the same bulls, when the bulls were apparently of as high or higher inheritance than that of the dams. If the hypothesis of dominance and recessiveness is true, the arithmetical average of the daughters as an index of the bull's would be in error when the dam possessed a higher level of inheritance than the bull. Positive conclusion as to the value of bull indexes in evaluating bulls must be withheld until more convincing information is at hand. In the meantime, the breeder should have an open mind toward the bull index, but should not depend too much upon it in giving direction to his breeding program.

The breeder of today must familiarize himself with all that is known about inheritance of characters in dairy cattle, learn how to test his herd for their genetic makeup, and use the system of breeding that is best adapted to his needs. Depending alone upon any one formula or single set of factors to give direction to the breeding program where inheritance is apparently so complex as in dairy cattle, is fraught with great danger.

Chapter 23

KNOWN INHERITED CHARACTERISTICS IN DAIRY CATTLE

WHILE AS YET COMPARATIVELY LITTLE IS KNOWN ABOUT INHERITANCE IN cattle, there are a number of characters the nature of the inheritance of which is known. Many of these characters are of economic importance, while others are mainly of interest for what they may contribute to the general knowledge of inheritance. A consideration of the more important of the known inherited characters of dairy cattle is essential for one interested in the breeding of dairy cattle. The value of a knowledge of the nature of the inheritance of the characteristics that are of economic importance is obvious. A knowledge of the nature of the inheritance of characters not of economic importance finds value in that it contributes to one's concept of how inheritance behaves in cattle. The characters for which the nature of the inheritance is more or less known fall into the following groups:

1. Inheritance of color
2. Inheritance of miscellaneous characters
3. Inheritance of lethal factors
4. Inheritance of characters affecting production

INHERITANCE OF COLOR [1]

The inheritance of color in cattle is governed by a large number of factors. These can be grouped into two classes: namely, a group of factors that influence the pigmentation of the hair, and a group of factors that influence the color pattern.

Factors that influence pigmentation. In cattle there are all degrees of shades of color, ranging from a jet black down to white, which is a complete absence of color pigment. These colors and shades are due to several different types of inheritance. These types of inheritances may be divided into four different groups, as follows:

1. Where the darker color is dominant or epistatic to the lighter color.
2. Where the darker color is inhibited from showing even though a gene for such a color may be present.
3. Where there is a mixture of two or more colors.
4. Where the mechanism for color production is lost.

Dominance of darker colors. Unless there are other interfering factors, the rule is that the darker color is dominant or epistatic to the lighter color.

[1] The paper, *Cattle Inheritance, I. Color*, by Ibsen, Genetics 18: 441–480, 1933, has been drawn upon for viewpoints of color inheritance.

Thus, the red of the Red Poll is dominant to the yellow of the Jersey or Guernsey, and the black of the Angus or Galloway is dominant to the red of the Red Poll.

Factors inhibiting darker colors. Failure of a darker color to express itself even though it is present in the genetic makeup of an animal is observed in many cases. It may take form in a complete suppression of color in parts of the body or the entire body, or it may lighten the coat color in various degrees. Dominant white spotting, to be discussed under color patterns, may be considered as one form of complete suppression of pigment in certain areas of the body. The black West Highland cattle of England become dun in the presence of a dilution factor (D), which acts upon the black to make it several shades lighter. A similar factor is found to act upon the red of the Hereford to dilute it to a yellow.[1] In the Jersey, Ayrshire, and Guernsey there is an intensity factor (I) which, when present, intensifies the color or makes it darker. The recessive (i) might be said in all probability to dilute the intense black of the Holstein and Angus. In the Ayrshire and Jersey there is a peculiar modifying factor (ML) of the black spotting (Bs). This factor intensifies the black color. M, representing much black, is dominant in the male; and L, representing little black, is dominant in the female. Thus a male of ML composition is black, and a female of that composition is red. The black females are homozygous for M. There are many other factors influencing the degree of pigmentation in cattle. Later work, undoubtedly, will bring to light many factors influencing this phenomenon.

Mixture of color. There are some cases where two colors may appear in the same animal. While this is also considered under color pattern, it must be mentioned here since it affects the degree of pigmentation of the hair. The most commonly noticed of these is brindling (Br). This is a character manifested by alternating bands of black and red hair. The nature of the inheritance is discussed under color pattern. The black spotting (Bs) in Ayrshires and Jerseys permits the black to be expressed upon red. In the Guernsey, too, is found a condition where jet black spots of various sizes may appear on the red.

Loss of color-albinism. An interesting mutation is that of a loss of the capacity to develop pigment in the hair, skin, and other parts normally pigmented. This condition produces albinos, of which there are a number of cases on record for cattle. Experiments with albinos at the University of Minnesota have shown that while albinism is due to a single recessive gene in the homozygous condition, all other genes for color or color patterns fail to express themselves except for a peculiar character referred to as a ghost pattern. When the gene for black (B) is present in the albino, a pattern of the nature of that aspect for a black and white animal can be seen under proper lighting conditions. The darker pattern is not caused by pigment but is due to a hair structure in which the medulla is absent. This hair structure absorbs more light than the normal hair with medullas to

[1] PITT. Jour. Genet. 9:281–302. 1920.

produce the ghost pattern. It is thought that albinism is due to the loss of a gene essential for the conversion of tyrosine into the pigment.[1]

Color patterns. While much work has been done in the study of inheritance of color patterns, the final word has not as yet been said on the nature of this type of inheritance. The general behavior of the major features is quite definitely known, but many of the factors for minor variations are not so well known. For discussion, the inheritance of color patterns may be divided into four groups:

1. Self (S) and recessive white spotting (s)
2. Dominant white patterns
3. Black spotting
4. Mixed colors

Each one of these groups has a number of modifying factors which will be discussed in connection with the main thesis.

Self and recessive white spotting. Recessive white spotting (s) is an allelomorph of self (S). An animal that is self is solid of color unless there are some other modifying factors present, as is usually the case. Self is dominant to recessive white spotting. The heterozygous self (Ss) animal shows the same characters as the homozygous (SS) one. For the recessive white spotting to show the animal must be homozygous, and such an animal will breed true. The Angus, Galloway, and Red Poll are representative examples of the selfed animal (SS) even though they are modified by a dominant inguinal white (In). If this factor is present, white will be found in the inguinal region.

Recessive white spotting is recessive as the name indicates, and is found in the Holstein, Shorthorn, Jersey, Guernsey, and Ayrshire. It is responsible for the white areas of the body, tongue, nose, lining of the mouth, and white of the eyes and the legs. The white areas on the body and legs vary greatly in extent. This variation is accounted for by a single pair of modifiers, little white, Lw lw. Lw is not completely dominant to lw. This permits three types of modification of the extent of white spotting, depending upon the combinations. Thus, the Lw Lw animal will have very little white; the Lw lw will have a medium amount of white; and the lw lw animal will have a large amount of white. With the natural somatic variation, these three will account for all the degrees of white spotting that is observed. The Ayrshire and the Holstein undoubtedly possess both of the factors, while the Guernsey and the Jersey possess but the Lw.

A second modifying factor of recessive white spotting is known as the pigmented leg factor (Pl). This factor is responsible for the pigmentation below the knees, which usually begins at the hoofs and extends upward. It is also responsible for a spotting about the head. Being a dominant gene, whenever an animal possesses it in either or both of the chromosome pairs, the character will be manifested. The gene is very common in the Ayrshire and Shorthorn, and may be present in some Guernseys and Jerseys.

[1] Petersen, W. E., Gilmore, L. O., Fitch, J. B., and Winters, L. M. Jour. Hered. 35:135. 1944.

Holsteins with the Pl factor cannot be registered. The small black spots sometimes found on the legs of Holsteins are not due to Pl factor, but more probably to another factor known as the distal leg (Dl) factor.

Dominant white. There are at least five dominant white genes in cattle. All of these will find expression in either a recessive white spotted animal or a selfed animal. They are the White Park cattle of England (Wp), the Hereford pattern (SH), the Dutch Belted (SD), the color-sided pattern (SC), and the Inguinal white (In). Of these the SH, the SD, and the SC are allelomorphs of the self and recessive white spotting. Therefore, only two of these genes can be present in any one animal.

The Hereford pattern (SH) is dominant; it produces a white head, feet, ventral side of the body, and tip of the tail, and a strip of white of varying size over the shoulder running parallel with the length of the body. The SH gene may be said to be responsible for both the white and the pigmented part of the pattern. It is incompletely dominant to self and completely dominant to recessive white spotting. A cross of a Hereford with an Angus produces an F_1 where the white is diminished. When the Hereford is crossed with a Holstein, there is no diminution of the white. Among the Herefords there is a great deal of variation in the amount of white and pigmented areas. This is accounted for by a number of modifying factors. One is the Lw factor, which behaves like the same factor in the Holstein. Another is the white restrictor (Wr), which restricts the amount of white on the dorsal part of the neck and shoulder. A third is the red eye (Re) which is completely dominant to its recessive (re); it is responsible for the red hair around the eyes.

Dutch Belted (SD) is responsible for the white belt encircling the chest. It is completely dominant to recessive white spotting and incompletely dominant to self. A cross of a Dutch Belted with an Angus produces an animal with a narrower belt. There are, undoubtedly, factors modifying the Dutch Belted pattern; none, however, have been studied sufficiently to warrant giving them genetic symbols.

Color sided (Sc) is the factor responsible for a wide white stripe along the backbone and another along the belly and brisket, which gives the animal the appearance of having a stripe of color along each side. There is no purebred American breed possessing this character. In Norway, however, there are two breeds, the Telemarks and the Troenders. It is also found in the Yak and Zebus. This factor is incompletely dominant to self and completely dominant to recessive white spotting.

Inguinal white (In) is a dominant gene, epistatic to self. It is responsible for the white hairs in the inguinal region. In recessive white spotting it cannot be ascertained because recessive white spotting usually is responsible for white in the same region. The Holstein, which is homozygous for recessive white spotting, possesses this factor, for when the Holstein is mated to self animals free from inguinal white the character appears in the F_1s.

Black spotting patterns. The inheritance of two black spotting patterns is known. These are black spotting (Bs) and pigmented skin (Ps). The black

spotting factor is found in the Jersey, Ayrshire, Brown Swiss, and in some cases probably the Holstein. The black spotting factor manifests itself by producing black hair on lighter pigmented areas. It also causes black pigment in the skin, hoofs, nose, tongue, mouth, and eyes if the animal is self. As has already been stated, black spotting is dominant and is modified by the much black (M) which is dominant in the male and produces a more intense pigment, and by little black (L) which is dominant in the female and produces red.

The pigmented skin factor produces skin spotting without pigmentation of the hair. This factor is dominant and is best observed on denuded parts of the body, such as the nose; however, it may appear on any part of the body. It is the factor that is responsible for the black nose in Guernseys, which is considered undesirable. The fact that a Guernsey may have a clear nose does not necessarily mean that she is free from the pigmented skin factor, because the gene may manifest itself by pigmentation on another part of the body. This factor is also found in the Shorthorn and the Hereford.

The author has also observed jet black spots on the red areas of Guernseys. The nature of this inheritance is not known, but it probably behaves as a dominant gene in very much the same way as the black spotting factor. The clean-cut demarcation between the black hair and the red hair would suggest that it is a different factor than black spotting (Bs), where the black gradually fades out to red.

Mixed colors. There are two types of mixed colors, both of which are well known and satisfactorily worked out from a genetic viewpoint. These are the brindle and the roan. Brindle is a character where narrow stripes of black hair show on a background of red. Two genes are involved in its expression; one is the dominant black spotting (Bs) gene which must be present, and the other is the dominant brindling (Br) gene. The Jerseys carry the Bs gene to a large extent but do not possess the Br gene; consequently, no brindling is found in purebred Jerseys. The Angus carries the Br gene, but it does not possess the Bs gene; and even if it did, the brindling would not manifest itself, since they are selfed for black. If Jerseys and Angus are crossed, brindling may appear in the F_2 generation, one of each of the important genes coming from each of the parental types. A limited amount of brindling occurs in the Guernseys. This would indicate that the Guernsey possesses the gene for brindling and also the black spotting gene. In the Guernsey the brindling is usually confined to the head and neck, but in scrubs it will be extended to the entire body.

Roaning is a condition where white hair is interspersed with pigmented hair. If the pigmented hair is red, it is known as red roan. If the pigmented hair is black, it is known as blue roan. The inheritance of this character is quite complex and is not so well known as most of the other color inheritances. It is generally agreed upon that factor N is needed; in the homozygous condition it produces white by inhibiting the expression of red. In the double recessive (nn) form the animal will be red. In the heterozygous (Nn) form the animal will be roan. That this condition is

necessary for roaning is generally agreed upon; however, there are other factors which modify the character roaning which are not so well agreed upon.

Ibsen explains the modifying factor tentatively by postulating a dominant roaning modifier (Rm) which acts upon the heterozygous (Nn) to produce a roan. The recessive rm rm would produce a red. If only the heterozygous condition Nn were necessary for roaning, all matings of white and red in the Shorthorn breed would be roans; but this is not so. Ibsen's postulation would account for the exceptions of red and white Shorthorn crosses in producing roans.

Color factors in different breeds. The color factors in the different breeds are as follows:

Holstein. On the basis of what is now known, the color formula for the Holstein is as follows:

BB dd II nn ps ps ss Lw lw pl pl WW Wn Wn Wp Wp
Bb Ps ps lw lw
bb Lw Lw

The Holstein is variable for pigmented skin where individuals may be double recessives or possess the dominant pigmented skin gene, and for the little white modifier of recessive white spotting. The Holstein is the least variable of any of the dairy breeds in the fundamental color factors. There is a recessive red. Animals having this recessive factor cannot be registered; whenever a red and white Holstein calf is dropped, it is a loss to the breeder of purebred Holsteins.

Jersey. On the basis of the present knowledge, the color formula for the Jersey is as follows:

bb br br Bs bs ML dd ii nn SS Lw Lw ww Wn Wn wp wp
Bb LL Dd ss
MM

The Jersey is variable for black, as it may be either red or black; for black spotting; for black spotting modifier; for dilution; and for self, as it may be either solid colored or white spotted and may be variable for the recessive white spotting factor (LW).

Ayrshire. The formula for the Ayrshire on the basis of present knowledge is as follows:

Bb Br br Bs bs ML dd II nn Ps ps ss Lw lw Pl pl WW Wn Wn Wp Wp
bb br br bs bs MM
BB Br Br Bs Bs LL Ps ps Lw lw pl pl
Ps Ps Lw Lw Pl Pl

The Ayrshire is the most variable of the dairy breeds for color genes. It may be heterozygous for the genes affecting black, brindling, black spotting, black spotting modifiers, pigmented skin, recessive white spotting modifiers, and pigmented legs.

Shorthorn. The color formula for the Shorthorn is as follows:

bb bs bs dd II Nn Rm rm Ps ps ss Lw lw Pl pl WW Wn Wn wp wp
nn Rm Rm Ps ps lw lw Pl pl
NN rm rm Ps Ps LW LW Pl Pl

The Shorthorn is variable for the roaning factors (N and Rm), pigmented skin, and the recessive white spotting modifier, little white, and pigmented leg.

Guernsey. The color formula for the Guernsey is as follows:

bb bs bs dd ii nn Ps ps ss Lw lw Pl pl WW Wn Wn wp wp
Bs bs? ps ps lw lw Pl pl
Ps Ps Lw Lw Pl pl

The Guernsey varies in its inheritance of genes for pigmented skin and white spotting modifier. Guernseys may, in some cases, possess genes for pigmented leg and black spotting.

The variables are:

Ps	ps
Lw	lw
Pl	pl
Bs	

Brown Swiss; Dutch Belted. There is not enough known about either the Brown Swiss or the Dutch Belted to warrant a color formula.

INHERITANCE OF MISCELLANEOUS CHARACTERS

Horns and hornlessness. The nature of the inheritance of the hornless condition was one of the first genetic factors worked out for cattle. At first it was assumed to be a simple Mendelian dominant-recessive phenomenon, in which the hornless condition was completely dominant to the horned condition, or a dominant inhibiting factor. More recently, it has been shown that the inheritance cannot be explained by a single factor, for in the F_2's and F_3's, scurs often appear. Ibsen postulates that all cattle are homozygous for horns and that, in addition, Polled cattle carry a dominant gene (P) which is completely dominant to its recessive and epistatic to the horned condition.[1] Crosses between homozygous polled and horned cattle produce mostly polled offspring, but some (mostly males) are either scurred or horned. To account for this, Ibsen postulates two other genes Ha (African horns) and Sc (scurred) as being involved. In the male Sc Sc or Sc sc is epistatic to P, and all males carrying the factor are scurred. In the female Sc must be homozygous to be epistatic to P. Ha probably behaves similarly. Males carrying P are horned whether they are homozygous or heterozygous for Ha.

Notched ears. In the Ayrshire and Jersey breeds a condition of a notch of varying sizes in the lower part of the ear has been observed.[2]

[1] White and Ibsen. Jour. Genet. 32: 33–49. 1936.
[2] Lush. Jour. Hered. 13: 8–13. 1922.

From a study of a number of matings, it seems to be due to a single Mendelian dominant gene. Bulls with "notched ears" and apparently heterozygous, transmitted the character to approximately one-half of their offspring.

Night blindness. This is a defect found in Shorthorns, which makes it impossible for them to see in lights in which other cattle can see perfectly.[1] The defect is one which affects the rods and cones of the retina, and behaves in such a way as to lead to the conclusion that it is due to a single recessive gene.

Umbilical hernia. Umbilical hernia has been observed in dairy cattle for a long time.[2] Not until recently, however, has there been any concerted attempt to ascertain the nature of its inheritance. The problem has been made difficult by the fact that it affects, in the main, only the males, and frequently those that may have the inherited character do not show it, because environment is a factor in its expression. There can be little question that the factor is recessive and that perhaps only one gene is involved.

Polydactyly.[3] Polydactyly is a condition in cattle where more than two toes are found. While it is not very common, it has been found sufficiently often to have made possible a study of its genetics. The character is recessive and probably only one gene is involved in the expression of the character.

Screw tail.[4] Screw tail or a kink in the tail is a condition that has been observed and studied in the Red Polled cattle. It manifests itself by a kinklike condition of the tail which is effected by a fusion of one or more pairs of adjacent coccygeal vertebrae. It has been shown to behave as a simple recessive Mendelian character.

Wry tail.[5] Wry tail, a condition in which the tail is set over to one side of the body, has been described in the Jersey. This likewise behaves as a simple recessive Mendelian character.

Defective teeth.[6] Defective teeth, a hair defect, and several other minor characters have been studied; and nearly all of them appear to be due to recessive genes.

Udder abnormality.[7] An udder abnormality which is inherited as a single recessive Mendelian character has been described in the Guernsey. The udder is usually poorly shaped, is of about equal development on both sides, but there is only one teat on the left side.

INHERITANCE OF LETHAL FACTORS

A lethal, as the name indicates, is a factor that causes death of the individual. Strictly speaking the lethal should produce death at or before

[1] Craft. Jour. Hered. 18: 215–218. 1927.
[2] Warren and Atkeson. Jour. Hered. 22: 345–352. 1931.
[3] Roberts. Jour. Hered. 12: 84–87. 1921.
[4] Knapp, Emmel, and Ward. Jour. Hered. 27: 269–271. 1936.
[5] Atkeson and Warren. Jour. Hered. 26: 331–334. 1935.
[6] Cole. Jour. Hered. 10: 303. 1919.
[7] Heizer. Jour. Hered. 23: 111–114. 1932.

birth. Sublethal should apply to the factors that do not cause death until some time after birth. At the present time about 25 lethals[1] and sublethals are known for cattle. This is more than for any other species, and there are undoubtedly still more to be discovered. Since most lethals are due to a single recessive gene, it is obvious that in the mating of animals each possessing the gene, one out of four of the progeny will be affected; two will carry the gene; and one will be free from it. The loss in calves in a population in which one or more lethal genes are present can be large. The more important of the lethal factors will be briefly discussed.

Achondroplasia. There are three types of achondroplasia, all dealing with some abnormality of the cartilage as it forms bone. Flat, long, and irregular bones may be involved.

Achondroplasia 1.[2] Achondroplasia 1 was the first lethal factor to be discovered in cattle. It is also known as "bulldog head" because of the shape and size of the head. The gene is incompletely dominant. In the homozygous condition the fetus becomes a monster and is usually aborted at from three to eight months of gestation. In the heterozygous condition the legs are shortened. The Dexter breed is a heterozygote for this gene. In mating Dexters one-fourth of the offspring are aborted as "bulldog" calves, one-half are normal Dexters, and one-fourth are normal legged animals known as the Kerry breed. The Kerrys breed true but the Dexters split into the three phenotypes. The gene for achondroplasia has been found in Jerseys.

Achondroplasia 2 differs from the other form in that the affected calves are usually carried to normal term and may live for a few days. There is also some difference in the malformation in which the lower jaw protrudes beyond the upper jaw. The gene is present in the Telemark cattle of Norway where it was first described. It has also been found in the Holstein, Jersey, Guernsey, and Ayrshire breeds.

Achondroplasia 3[3] is found in the Jersey breed, having been discovered by workers at the California Station in an inbreeding project. The heads of the affected individuals are short and wide, the lower jaw protruding, and the palate usually is cleft. Sometimes the legs are shortened and the pasterns flexed. Affected individuals usually die shortly after birth but an individual may live up to fourteen months.

Short spine lethal.[4] This condition has been observed only in the Oplandske breed of cattle of Norway. It is characterized by a fusion or absence of a number of the vertebrae of the neck, back, and tail, producing an exceedingly short neck and body. Other parts of the body are normal. It behaves as a simple recessive character, since 25 per cent of the offspring of heterozygous parents are affected.

Amputated leg lethal.[5] Amputated leg lethal has been found in the

[1] Shrode, R. R. and Lush, J. L. Adv. in Genetics. 1:209–261. 1947.
[2] Wriedt and Mohr. Jour. Genet. 20: 187–215. 1928.
[3] Mead, S. W., Gregory, P. W., and Regan, W. M. Jour. Hered. 37:183–188. 1946.
[4] Mohr and Wriedt. Jour. Genet. 22: 279–297. 1930.
[5] Wriedt and Mohr. *Op. cit.*

Holstein breed of Sweden. It is a complementary gene of the short spine, as the bones not affected by the short spine are affected by this factor. The legs are shortened, and the feet and lower parts are entirely missing. The lower jaw is vestigial or entirely missing, and the upper jaw is shortened or curved back under in the position where the lower jaw normally would be. This, too, behaves as a simple recessive Mendelian character.

Hairless lethal.[1] Hairless lethal has been reported only in the Holstein breed of Scandinavia. The calves, born at the normal time, are entirely lacking in hair and live for but a short time. Like the other lethals described, it, too, is apparently due to a simple recessive gene.

Epithelial defect.[2] The epithelial defect, which is lethal, is manifested by a defective epithelium noted at the birth of a calf. The skin below the knees is denuded, and the mucous lining of the nostrils, mouth, tongue, palate, and cheeks also is affected. One or more of the claws is underdeveloped, and the integuments of the muzzle are defective. This condition has been described for the Holstein breed in America, and at least one Shorthorn calf has been reported that answers to the description of this congenital defect.[3] In all cases where the defect has been known in the Holstein breed, the ancestry can be traced back to the bull Sarcastic Lad through at least two lines.

Impacted molars. A lethal has been reported for the Milking Shorthorn in which the mandible is shortened and the premolars are impacted in the jaw bone.[4] The molars are irregularly placed and the jaw bulges or is broken on the lateral surface. The calves are dropped at normal time but die during the first week. This lethal is also due to a simple recessive factor.

Additional Lethals. The following are a list of additional lethal or sublethal factors that have or seem to have a genetic basis.

General ankylosis: All joints are ossified to prevent flexion at the joints. Found in Black and White lowland cattle in Germany.

Ankylosis of lower jaw: The lower jaw is fused with the upper jaw at point of articulation. Found in Lyndal breed of Norway.

Agnathra: Partial or complete absence of the lower jaw. Found in Jerseys in the United States.

Hydrocephalus: Enlarged skull filled with a fluid; reported in Holsteins in Michigan.

Skull defect: The bones in the skull failed to close exposing the brain to trauma. Jersey, United States.

Micromelia: Short legs differing from the amputated leg condition. Found in Russian cattle.

Deformed limbs: All legs markedly deformed. Found in Friesian cattle in Russia.

Missing Phalanges: One or more of the phalanges absent. Found in Swedish cattle.

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[1] Mohr and Wriedt. Jour. Genet. 19: 315–336. 1928.
[2] Hadley and Cole. Wis. Agr. Expt. Sta. Res. Bul. 86. 1928.
[3] University of Minnesota.
[4] Heizer and Hervey. Jour. Hered. 28: 183. 1937.

Mummification: Fetuses mummified in the uterus before birth. Found in Danish Reds.

Lameness: Calves, unable to stand, die in a day or a few days after birth. Found in Red Danish Breed.

Muscle contracture: Spastic contraction of extensor muscles of neck and limbs. Found in Norwegian, Danish Red, and Holstein breeds.

Closed nostrils: Membrane closure of nostrils producing suffocation. Found in Mountain breed of Croatia.

Artresia Ani: The anus is closed. Surgical opening does not prevent death. Found in Indian cattle.

Congenital spasms: Found in Jerseys as the result of continued inbreeding.

Congenital dropsy: Generalized hydration of the body. Found in Swedish breeds.

Sex-linked lethal: Males affected die. No specific lesions observed. Found in Angel cattle.

INHERITANCE OF TWINNING

There is positive evidence that twinning is an inherited character. According the recent figures, twins represent about one-half of 1 per cent of the calvings, and 1 per cent of the total number of calves. The per cent of twinning varies with different breeds. In Sweden it is found more frequently among the Holsteins than in the Red and White breed, and in this country it is much more frequent in the dairy than in the beef breeds.[1] In the Kansas Station's Holstein herd the twinning percentage was 8.84 per cent, indicating that in this herd the factors for twinning are present quite generally. Because twinning is not a desirable character in cattle, no one has ever bred for this character. As a result not much is known as to how successful one would be in attempting to establish a herd having the twinning character quite general. With sheep, where selection for this character has been general because of the desirability, flocks have been established that have been quite pure for the character.

As environment is an influencing factor in the production of twins, the exact nature of the inheritance is not determined. Animals that may have the factors for twinning may not necessarily produce twins because of a number of possible interfering conditions. The competition for the survival of the implanted embryos is great. A cow that may have the inheritance for secretion of two or even more ova at each ovulation may never carry more than one fetus to normal term because of the many hazards encountered.

Formerly it was thought that monozygotic twins rarely if ever occurred in cattle. It is now well established that identical twins occur with sufficient frequency to make their use practical in research work of nearly all kinds. The frequency of identical twins is not definitely known but estimates are that they occur about once in each one thousand parturitions. Hundreds of monozygotic cattle twins have been inspected by the author. They may possess mirror imagery or be alike.

Freemartin. When a heifer is a twin to a bull, it is known as a freemartin. Ninety-two per cent of all freemartins are sterile because of the

[1] JOHANSSON. Z. Züchtg: B. Tierzüchtg.u. Züchtgsbiol. 24: 183–263. 1932.

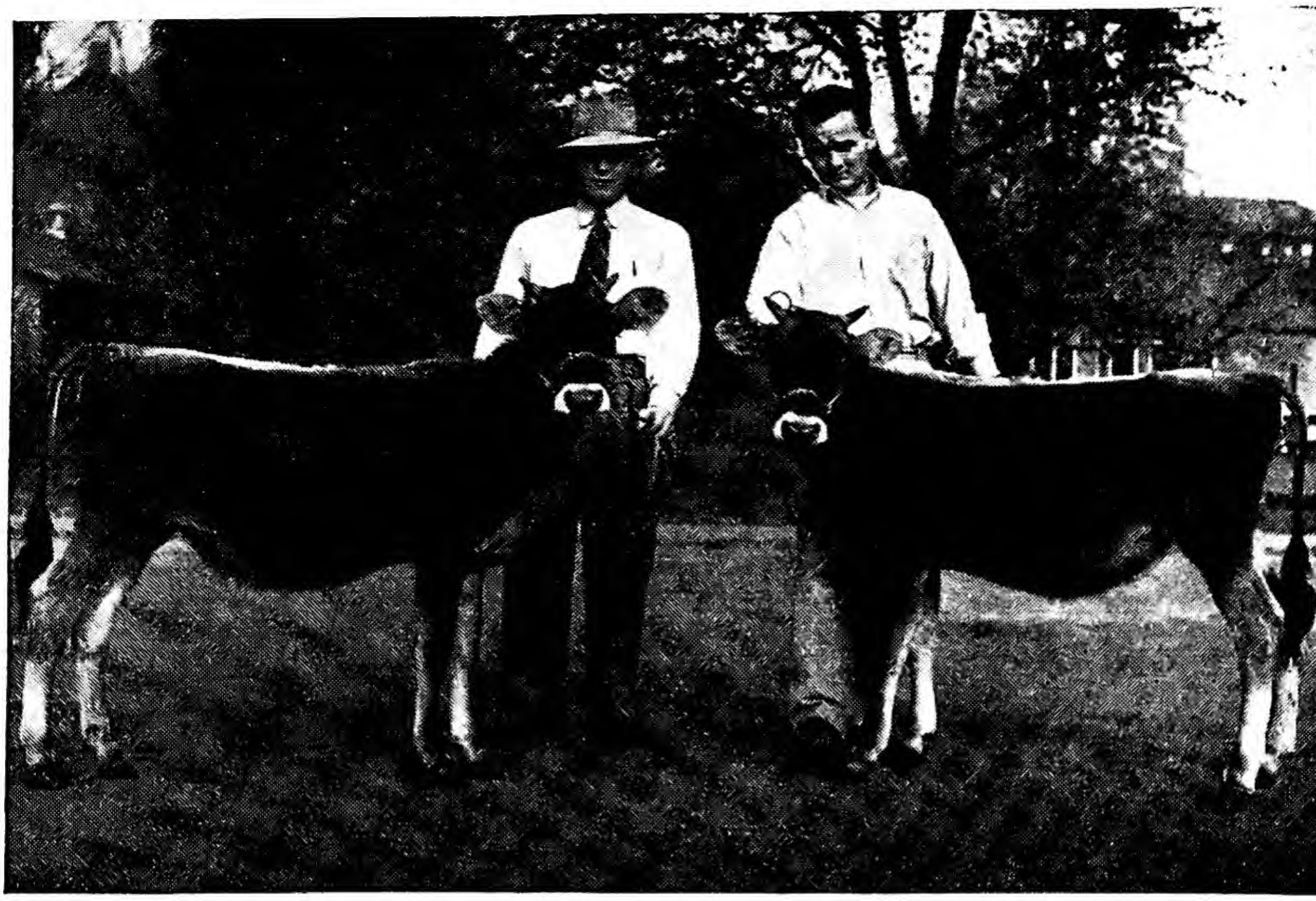


Fig. 54. A set of identical twins of Jersey-Brown Swiss Cross is pictured here.

inhibitory effect the embryonic male hormones have upon the development of the female reproductive organs. Freemartins, like all twins, are much smaller at birth than singletons. They average from 70 to 80 per cent of the normal weights of single-born calves. With freemartins, as well as with all twins, about five times as many are stillborn as are singletons. They, too, have less vitality; the records show that 12½ per cent of twins die as young calves, whereas the average losses for all calves is about 4.2 per cent, under the same environmental conditions.

INHERITANCE OF FACTORS CONCERNED WITH PRODUCTION

There are so many factors involved in inheritance of milk and butterfat production that the knowledge as to the nature of the inheritance is speculative. The theories concerning the inheritance of milk and butterfat production have been evolved largely from circumstantial evidence or meager data and must, therefore, be held subject to such changes as new evidence may determine. Before considering the theories and what is known about these most important characters, it is well to consider the physical basis for milk and butterfat production.

In order to produce milk, the cow must have the mechanism which manufactures milk; a large number of factors undoubtedly are involved in the development of this mechanism. Then efficient use of the mechanism must be made, and other factors are necessary for this. Under the head of the factors for the development of the mechanism may be considered factors influencing the size of the animal, the capacity for feed,

the metabolism of feed, the size of the udder, and the quality of the udder. Factors affecting efficient use of the mechanism may be divided into those affecting milk production, fat production, and persistency. In addition to these considerations the practical dairyman is interested in the inheritance of type, longevity, breeding efficiency, and vigor.

Size. A number of people have shown that size is correlated to a certain degree with production. There is evidence that large animals may not be so efficient as some smaller animals, yet there is a limit to the smallness of the animal for profitable production. In the case of the inheritance for size there are so many factors involved that nothing specific about individual factors is known. That size is inherited is supported by a large amount of evidence. Different breeds are characterized by differences in size, and since all breeds at one time originated from the same common ancestry, different factors for size have been retained by different breeds in their development. The larger breeds must have a number of factors for size that are absent in the smaller breeds. The effect of selection for size factors is also evidenced in strains and families within the breeds. There is ample evidence in the records of practical breeding to show that by selection people have established strains and families of cattle that are noted for much larger size than is normally found within the breed.

Crossbreeding has furnished a clue as to the possible nature of some of the factors involved in size. The F_1s in crossbreeds where the parents vary greatly in size are intermediate, but they tend to be closer to the size of the larger parent. Thus, a cross of Jersey and Holstein produces individuals that are intermediate but more nearly the size of the Holstein than of the Jersey.

Inbreeding experiments have commonly resulted in reduced size of the inbred animals. This fact, together with the fact that in crossbreeding the offspring are closer to the size of the larger parent than the smaller parent, indicates that a number of the factors responsible for size are dominant. From the larger number of variations in degree of size between individuals within a breed and between breeds it is apparent that a large number of genes are involved in the inheritance of size.

Capacity for feed. Dairy animals vary greatly in their capacity for handling feed. A portion of the ability to handle large amounts of feed can be accredited to development, since animals that have been heavily fed will be able to consume more feed than those which have been lightly fed; yet most of the ability to handle feed is due to inheritance. The differences in the ability of animals to consume roughage is the most pronounced. At the Minnesota Station variations in the ability of animals to consume roughage were found to be from two and one-half to four pounds of hay per 100 pounds of live weight per day. Daughters of one bull had uniformly large capacity for handling of roughage regardless of their dam's capacity. While no work on the specific inheritance of capacity for feed has been reported, such inheritance is probably due to many factors, some of which, from the influence observed of one parent upon the daughters, would appear to be dominant. This variation in the ability

of dairy cattle to handle roughage is an important economic factor in the breeding of dairy cattle.

Roughage yields more nutrients at a lower cost per acre than do the cereals. Cows that surpass in their ability to use large amounts of roughage have a distinct economic advantage over those that are lacking in this respect.

Udder size. A large udder is one of the essential prerequisites for high production, although large udder size is not a guarantee of high production. Development of the udder is due to the action of hormones, for which there are probably several hereditary factors. The ultimate size to which an udder may be developed by the action of these hormones is undoubtedly dependent upon some other inherited factors. How many factors are concerned in the udder development is not known, nor is the nature of any of the factors known. In crossbreds of beef and dairy breeds, the udders of the F_1s are a little larger than half way intermediate between the two parents; this would indicate that at least some of the factors for udder size are dominant, although it is possible that the effect of heterosis may be a contributory factor to the observed fact. To offset this, it is possible that the beef breeds contribute some factor or factors which inhibit the growth and development of the udder.

Quality of udder. It is well known that there are great differences between individuals in the quality of udders. It is also common knowledge that the udder of poor quality produces more than does one of poor quality. The poor quality is due to a relatively large amount of connective tissue and a corresponding lesser amount of secreting tissue. Again, the nature of the inheritance of "quality of udder" is as yet speculative. It has been generally observed that there is a tendency for dams with poor quality udders to pass this characteristic on to the daughter. Bulls are also known to have passed this characteristic on to their daughters. Breeders who have persistently selected for good quality of udders have attained a reasonable degree of success, but the slowness with which success is attained lends support to the contention that the inheritance of quality of udder is complex.

Activity of the milk making mechanism. It is common knowledge that cows with large udders of good quality may sometimes be rather poor producers.

There are several possible causes, of genetic origin, for the udder to fail to secrete the maximum amount of milk per unit of tissue provided the nutrient intake is adequate to support higher levels of production. One is a failure of the endocrine system to supply the necessary hormones in optimum amounts. Another is the failure of adequate blood supply to the gland; a third is the lack of the individual cells to respond to greater production; and a fourth is the failure to get all of the milk out at each milking.

Endocrine activity,[1] in relation to udder development and milk secre-

[1] PETERSEN, W. E. Recent Progress in Hormone Research. 2:133–158. 1948.

tion, is very intricate and complex and far from being fully understood. It is known, however, that prolactin, a hormone secreted by the anterior pituitary, is essential for milk secretion. It has also been demonstrated for both cows and goats that production in some animals may be greatly increased by injection of prolactin. This indicates that secretion of this hormone in quantities not sufficient to maintain high activity of the secretory tissue is sometimes a factor. Goats [1] have been found that increased milk production up to 262 per cent. In cows, many workers have obtained increases in milk production following the administration of prolactin, including one case in which the author obtained more than 60 per cent increase. For the most part, however, increases in this species seldom exceeds 25 per cent and often no augmentation is obtained. The thyroid is also definitely concerned with maintaining milk secretion, since ablation [2] of this gland causes cows to dry off and feeding of thyroxin increases both milk and fat production. In some cases, at least, it would appear that lack of inheritance for the secretion of the required amounts of thyroid substance is a limiting factor.

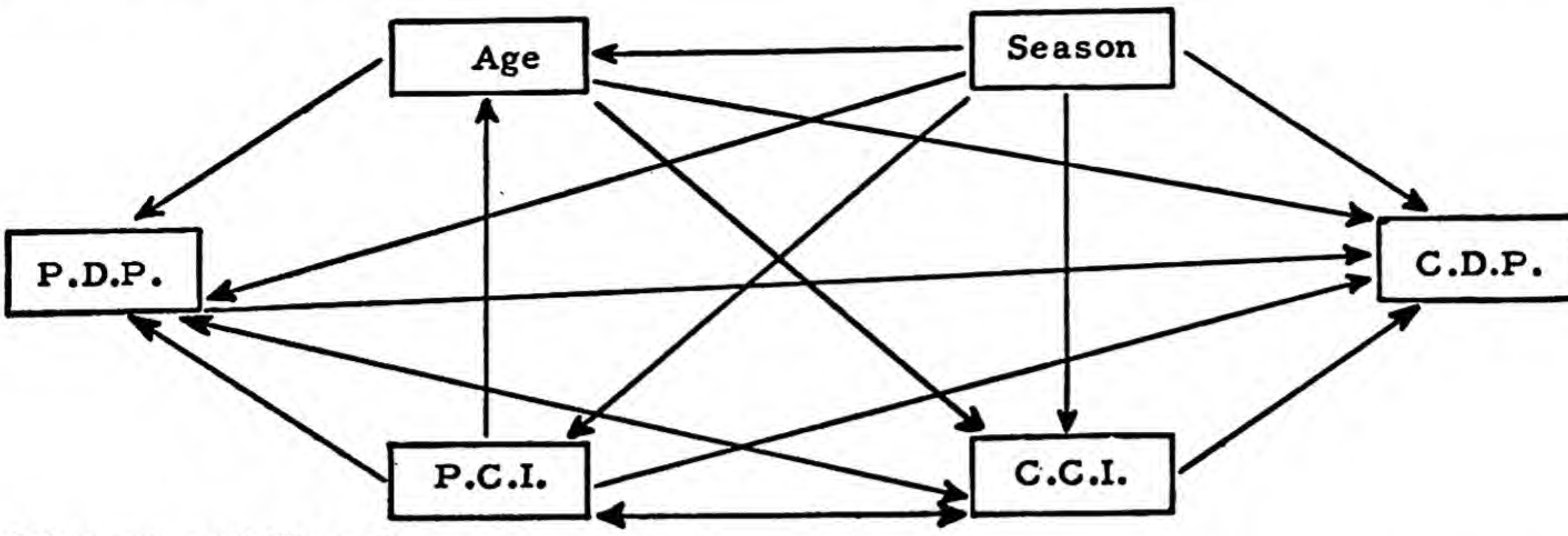
It has been shown that about 400 volumes of blood must pass through the udder of the cow for each volume of milk produced.[3] Any constriction of the vascular system or failure of its optimum development would therefore limit production of milk. Ergot, which constricts the vascular system, has been shown to have a marked depressing effect upon milk secretion. It is theoretically possible that the individual cells lack the capacity for producing optimally regardless of how well they may be supplied with the necessary precursors and hormones. No evidence as yet exists for support or rejection of such a hypothesis.

Failure of the cow to respond to the milking stimulus with a complete let-down of milk has been demonstrated to be an important factor influencing the level of production. This is discussed in this chapter, under *Milking Factors*.

Since a definite amount of nutrients is required for any given amount of milk of a certain fat percentage, it is evident, too, that the animal must have inherited capacity for handling enough feed to take care of the nutrient requirements for production. As has been previously stated, lack of inheritance for food capacity is frequently the limiting factor for high production.

Milk and fat production. In general, there are two views as to the nature of milk and fat inheritance. One is that there is a large number of dominant and recessive Mendelian factors, and the other, supported by a number of people, is that milk production is the result of an inheritance that is cumulative; this means that each gene of the pair contributes toward the expression of a character. The hypothesis that the majority of factors for milk production are dominant finds much support. As has been previously indicated, recessive characters are easier to establish, for when a

[1] ASDELL. Cornell Univ. Agr. Expt. Sta. Memoir. 198. 1936.
[2] SPIELMAN, A. A., PETERSEN, W. E., AND FITCH, J. B. Jour. Dairy Sci. 27:441. 1941.
[3] SHAW, J. C. AND PETERSEN, W. E. Am. Jour. Physicl. 123:183. 1948.



Johansson and Hansson

Fig. 55. Diagram showing the complex interactions between the age at calving, preceding (P.C.I.) and current calving intervals (C.C.I.), preceding (P.D.P.) and current dry periods (C.D.P.) and the season of calving. The line of action is indicated by arrows.

character is expressed, the animal is homozygous for such a character. In cases where the characters are the result of dominant genes, the undesirable recessive gene may be present; it cannot be ascertained from the type of the individual, and can only be described through inspection of the progeny.

Experiences that dairymen have had in the mating of heavy producers, when some of the offspring are decidedly inferior to one of the parents, would lend support to the hypothesis that the characters for milk production are dominant, and that high producers may carry many recessive factors for low production. Turner has added more evidence to the probability of the dominant-recessive hypothesis.[1] After studying the distribution of production in mixed breeding, he postulated that such distribution could be accounted for by 18 Mendelian factors acting on the basis of dominance and recessiveness. Evidence for the cumulative hypothesis finds support in the observed production as a result of crossbreeding.[2] Where beef breeds are crossed with dairy breeds, the F_1s are intermediate, with the milk production being nearer the level of the high producing parent and the fat percentage nearer the level of the low testing parent. Crosses of extremes within the dairy breed have not been intensively studied, but apparently there is some evidence that this, too, results in production levels intermediate between the two parents. With the crossbreeding of beef breeds and dairy breeds, the results can be questioned on the basis that, since the beef breeds have factors for beef production which may be epistatic or dominant to the factors for milk and fat production, such crosses cannot reveal the true nature of the inheritance of factors for milk and fat production. It is possible that a combination of dominant and recessive factors and cumulative factors are responsible for milk and fat production.

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[1] Turner. Mo. Agr. Expt. Sta. Res. Bul. 144. 1930.
[2] Gowen. Jour. Agr. Res. 15: 1–57. 1918.

More evidence for the support of the dominant hypothesis lies in the performance of prepotent sires, where the daughters are invariably of a production level that would be more nearly that of the sire. At the Minnesota Station, no correlation was found between the dam's record and the record of the daughters of such bulls although the dams varied materially. It would appear that the daughters' inheritance for production had come mainly from the sire. This may be explained by postulating dominance of the factors for milk production and that the sire was relatively homozygous. There are also many records of bulls siring daughters whose production levels are consistently lower than their dam's. This is more difficult to explain unless one postulates their possessing dominant inhibitory factors.

The only conclusion that can be positively drawn is that the inheritance of butterfat and milk production is extremely complex.

Fat percentage. The question of whether fat percentage is an inherited character is at the present debatable. The fact that different breeds are characterized by fairly definite fat content of the milk has lent support to the hypothesis that percentage of fat is a definite inherited character. Fat percentage is merely the ratio of fat to milk; and if it is a definitely inherited character, that which influences one should influence the other to the same extent. This is not so. Certain high fat feeds will increase the fat content of milk without affecting the amount of milk. The fact that with the advance of lactation the daily milk production drops more rapidly than the daily fat production, resulting in an increased fat percentage, must be taken as evidence against the inheritance of fat percentage. Another argument against such an inheritance is based on the well-known wide daily variations of fat percentage. Recent advances in the knowledge of the physiology of milk secretion indicate that milk fat is synthesized independently of the other ingredients of milk; this should be considered as additional evidence opposed to the inheritance of fat percentage as a definite character.

Rather than to consider fat percentage as a definite inherited character, it would seem more logical to consider the inheritance of capacities for milk and fat production separately. By postulating a few factors affecting milk and fat production separately, all the variations in fat percentage can be explained.

Persistency. Persistency, or the ability to maintain a high daily milk flow throughout the lactation period, is one of the very important characters essential for economic production. That persistency is an inherited character cannot be doubted. Beef breeds, in the main, lack persistency, frequently going dry after five or six months of lactation. Crosses between beef breeds and dairy breeds are intermediate in persistency.

A hormone *prolactin*, secreted by the anterior pituitary body, is necessary for the initiation of lactation. Recent work indicates that a continued secretion of this hormone is necessary to maintain milk production. Injection of the hormone into lactating animals with poor persistency records resulted in marked improvement. This would seem to indicate that the

inheritance of the factors for persistency are concerned with the anterior pituitary body. Attempts at determining the nature of the inheritance have met with little success and have indicated only that it is, in all probability, a complex inheritance.

No characteristic is more subject to variation due to environmental influences than is persistency. It is therefore more difficult to ascertain the genetic influence on this characteristic. Several studies have shown, however, that the slope of the lactation curve is markedly influenced by heredity. Swedish workers [1] have estimated that from 15 to 30 per cent of the variations encountered in persistency is determined by heredity. These same workers have estimated that heredity accounts for 30 to 40 per cent of the variation in milk or butterfat yield for 300 days and from 70–80 per cent of the butterfat percentage. The rest of the variation for these characteristics is assumed to be due to environmental factors. Studies at the Minnesota Station [2] indicate that heredity played a major role in accounting for the variation in persistency.

Type. Selecting and breeding for type is one of the oldest objectives of breeders. As the character "type" involves all of the body conformations and proportions of body parts, it is reasonable to assume that it involves the most complex inheritance of any of the dairy characters. There is conclusive evidence that many factors are required for a single part of the body. Since literally scores of parts of the body are involved in the whole animal, and since for the correct type each part not only must be shaped correctly but also must be proportionate and in harmony with every other part, it is easy to visualize hundreds of factors as being involved. In spite of the great complexity of the inheritance of type, there are records of many successes of breeders in securing herds of superior type. While many matings of parents of superior type have resulted in offspring of poor or mediocre type, there are also many examples of animals that breed practically true for excellent type. The fact that in the Jersey, Guernsey, and Holstein breeds three direct generations have won Grand Championships at the National Dairy Show, must be taken as prima facie evidence that good type is transmitted. That good type animals are not always secured from the breeding of superior types does not detract from the fact that good type is inherited, but contributes to the contention that the inheritance is very complex and that in all probability there are more factors involved in its inheritance than in any other.

Vitality and vigor. Like other important characters of dairy cattle, the inheritance of vitality and vigor is not known. There is, however, plenty of evidence that a large number of factors are involved and that vitality and vigor can be bred by proper selection. In plants, where more genetic work has been done than with animals, it is found that a large number of factors are involved in vitality. Vitality and vigor are the first

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[1] Johansson, Ivar and Hansson, Artur. Kungl. Lantbr. Tidsks. Nr. 6½: 1–127. 1940.

[2] Ludwick, T. M., Petersen, W. E., and Fitch, J. B. Jour. Dairy Sci. 26:447–455. 1943.

characters to be lost in inbreeding; this lends support to the contention that the mere absence of one of the many dominating genes for vigor and vitality may be responsible for the loss of this character. As loss of vigor and vitality is generally observed in the inbreeding of dairy cattle, it is apparent that cattle are heterozygous for many of the factors involved. The occasional weak offspring from vigorous parents can be accounted for by a combination of recessive factors for vigor from heterozygous parents.

Resistance to disease. With most highly infectious diseases of cattle it is questionable whether there is any material inherent resistance. For other diseases it has not been proved whether there is inherent resistance among individuals. On the basis of what is known in plant breeding it is reasonable to believe that there may be individuals among cattle which have a higher degree of resistance to some diseases than others. Plant breeders have established many varieties of plants resistant to devastating diseases. When more is known of possible individual resistance to disease in cattle another tool becomes available for use of the breeder in improving cattle.

Milking factors. There are at least two types of inherited characteristics that effect milking. One is hardness of milking and the other is the promptness and completeness with which the cow responds to the milking stimulus.

Because of the hardness of milking, cows may require from one minute to more than 15 minutes for removal of the same quantity of milk. It is not uncommon to find cows that require 10 more minutes per day than the normal for milking. Assuming such cows are milked 300 days each lactation, a total of 50 hours more are required for milking time. Studies now in progress by the author have demonstrated that hardness of milking is inherited. Daughters from hard milking cows tended to be harder milkers than the normal. The variations found in these studies indicate that several genes are involved in the inheritance of the hardness or ease with which cows milk.

Limited studies indicate that failure of cows to respond with a complete let-down of milk at each milking may be a major factor in some cases of poor persistency. A characteristic of these cows is great variations in the amounts of milk obtained from milking to milking and probable infrequency of complete emptying of the udder. Studies [1] of one such cow and her three daughters emphasize the depressing effects of this abnormality upon production and indicate that it is inherited. When this cow was handled so she responded with a complete let-down of milk, at each milking she increased her milk production by over 60 per cent for a lactation period of 305 days. That the abnormal behavior is inherited is supported by the fact that two of the three daughters presented similar idiosyncrasies.

DIFFICULTY IN DETERMINING GENETIC ROLE IN PRODUCTION

The total production of a cow is the sum of the interaction of many factors, part genetic and part environmental. The difficult problem for the

[1] Petersen, W. E. and Gilmore, L. O. Jour. Animal Sci. 5:399. 1946.

student is that of segregation of the genetic from the environmental factors. Aside from feeding and management other factors are graphically illustrated in Figure 55 with arrows indicating the direction of the interplay.

The use of monozygotic or identical twins will enable research workers better to arrive at environmental influences, since in this case the heredity is kept constant within pairs.

Chapter 24

SYSTEMS OF BREEDING

SYSTEMS OF BREEDING ARE CLASSIFIED UPON THE BASIS OF CLOSENESS OF relation of the animals mated. A knowledge of these systems and of what can be achieved through the use of any of them is of considerable value to the breeder of dairy cattle. Although very little experimental work has been done to give us adequate data for complete evaluation of the different systems of breeding, a discussion of these systems and of their uses and values in the breeding of dairy cattle will follow. The systems of breeding generally recognized are crossbreeding, outcrossing, linebreeding, inbreeding, and brading up. In addition to a discussion of the systems of breeding, it is both of interest and value to consider the methods used by the noted breeders of the past.

Crossbreeding. Crossbreeding is the mating of either purebred or grade animals of two distinct breeds. It is obviously not available to the breeder of purebred cattle, and can be used only in the beginning by one who wishes to establish a herd of high grades. Crossbreeding has been resorted to by dairymen to a considerable extent under the following conditions: in the beginning of a grading-up program; when it is deemed advisable to raise beef types from dairy animals; in attempts to combine the high fat content of the milk of Jerseys or Guernseys with the large milk yield of low fat content of the Holstein; and to increase the fat content of the milk to meet market demands. Crossbreeding has also been resorted to for experimental purposes to determine the nature of the inheritance of milk, fat percentage, and beef characteristics.

Crossbreeding for grading up. The owner of a mixed herd who desires to grade up such a herd by the use of a bull of a certain breed, naturally will secure crossbred stuff. As such an owner continues to use bulls of the same breed, he gradually develops a herd having all the characteristics of the breed which the bulls represent, and the undesirable characters of the crossbreds will be gradually eliminated. Thus, the problem of having a herd lacking in uniformity due to the interaction of the characters of the two breeds that are crossed is only a temporary one and need not be given serious consideration.

Crossing dairy cattle with beef bulls. Beef bulls have been used to a considerable extent on cows of dairy breeding for the purpose of improving the beef qualities of the calves. Beef bulls of dominant color and color patterns are preferred because the offspring will then be uniform in that respect. Angus crosses will be solid black and Hereford crosses will have the Hereford pattern, but Holsteins and Jerseys when crossed will be black instead of red. Since the offspring of these crosses are sold for beef, there is no further breeding problem to be encountered. Studies of beef-

dairy crosses at the Maine Station showed that the inheritance of beefiness is intermediate between the dairy and beef types;[1] for Angus-Jersey crosses the forequarters resembled more nearly the beef type, while the hindquarters were more like the Jersey type. Similar experiments at the Wisconsin Station corroborated the work of the Maine Station.[2] It is therefore apparent that the use of beef bulls on dairy type cows will produce offspring of considerably greater value for beef purposes.

Crosses to increase the fat content of the milk. In certain markets the demand for higher fat percentage of the milk, with resulting premiums for milk of high fat content, has forced dairymen to use bulls of the high testing breeds on Holstein cows. This has resulted in a mixture of colors that is generally undesirable. If a bull of the same breed is used on subsequent crosses, there will ultimately be a switching of the breeds, because gradually the blood of the high testing breed will be increased to such an extent that only its characteristics will remain.

Several experiments involving the crossing of different dairy breeds have shown that in general the offspring are intermediate between the two parents for fat percentage and amounts of milk. In general the milk yield of the hybrid will be somewhat nearer to the level of the high producing parent and the fat percentage nearer to the level of the low testing parent. This has led some to conclude that the factors for milk production are partially dominant, and that those for fat percentage are more recessive. If bulls of different breeds are used alternately in crossbreeding, problems of lack of uniformity in types and particularly in colors are encountered. It is also to be expected that a certain amount of segregation will make for great variability in the fat content of the milk as well as in the amounts of milk. In this case fat per cent and amount of milk will vary inversely. On the basis of the amount of evidence that is now available the desirability of crossbreeding is questionable.

Crossbreeding for experimental purposes. Two types of crosses have been made for the purpose of studying inheritance. One is the cross of beef and dairy types, and the other is the cross of extremes in the dairy breeds. These crosses yield valuable information on the inheritance of certain characters, such as color and the horned condition. The validity of the results in interpreting the nature of the inheritance of such complex characteristics as milk and butterfat production and beef is questionable. In beef-dairy crosses it is reasonable to assume that a large number of the factors responsible for either one of these crosses are not allelomorphic, and that undoubtedly factors for both milk and beef production are dominant or epistatic. It is therefore probable that there will be a conflict for expression of these characters in the hybrid, resulting to a certain extent in an incomplete expression of both sets of characters. This conflict would give the appearance of an intermediate inheritance, which is as has been observed. Crossing of dairy breeds, while uncomplicated by

[1] GOWEN. Jour. Agr. Res. 15: 1–57. 1918.
[2] COLE. Proc. World's Dairy Congress 2: 1383–1388. 1924.

the factors for beef production, is also subject to criticism as a means of studying the inheritance of amounts of milk and fat percentage.

Since all the dairy breeds are fairly well specialized for certain characteristics and since no crossing between the breeds has taken place for a long time, heterosis can be expected to be a factor in the hybrids. This would invalidate the data as a means of studying the inheritance of milk and fat percentage. In nearly all the crossbreeding experiments of different dairy breeds it has been observed that the hybrids have milk yields closer to the level of the high milk-producing parent and a fat percentage closer to the low testing parent. Fat percentage has been interpreted as being an inheritable character, when possibly it is the result of two inherited characters. It is possible that instead of fat percentage being the inherited character, the capacity for total fat production is the inherited character and the fat percentage is the ratio between the two inherited characters. This finds some support in the fact that the fat production of the hybrids is about that of the high producing parent; with an increasing amount of milk inherited from the higher milk-producing parent there will naturally be a decline in the fat percentage. This interpretation, too, lends support to the hypothesis that factors for milk production are dominant. It is clearly evident that more experimental work is necessary before positive conclusions can be arrived at.

Crossbreeding for commercial herds. The Bureau of Dairying [1] has carried on experiments with reciprocal two-breed crosses for Jersey × Holstein and Holstein × Red Dane and one-way crosses of Jersey × Guernsey, Holstein × Guernsey, Red Dane × Jersey, and Red Dane × Guernsey of which 50 crossbreeds have completed production records of 365 days, milked three times daily. All parents were purebred. The first records of the crossbreds are compared with the first record of their dams in the following table:

	Milk	Butterfat		Age	
	Pounds	*Per Cent*	*Pounds*	*Years*	*Months*
50 two breed crosses, average	12,958	4.56	586	2	2
50 dams, average	10,253	4.57	445	2	4
Average difference	+2,705	−.01	+141		
Number daughters better than their dams	41	20	47		

One of the problems in a crossbreeding program is what to do with the crossbreds. If bred back to either of the parental breeds much of the supposed benefits from crossbreeding would be lost. Introduction of a third breed is suggested, after which, theoretically, either of the first two parental breeds may be used without much loss in heterosis. To date 27 three-breed combination cows have completed 365 records on three-times-daily milking that can be compared to their dams as follows:

[1] BDIM—Inf—30 Suppl., April 1947.

	Milk	Butterfat		Age	
	Pounds	*Per Cent*	*Pounds*	*Years*	*Months*
27 three-breed crosses, average	13,130	4.64	618	2	2
27 two-breed dams, average	13,165	4.62	604	2	2
Difference	−35	+.02	+14		
Number of daughters better than their dams	17	11	17		

It will be noted that in the two-breed cross a significant increase in both milk and butterfat production was obtained. In the three-breed cross the production level was maintained.

Outcrossing. Outcrossing is the term applied to the system of breeding within a breed, the parents being selected from distantly related strains. Many people believe that outcrossing produces better results than closer breeding. Some breeders believe that crossing certain strains produces better results than the crossing of other strains, and refer to this phenomenon as "nicking." Whether this is the case cannot be positively stated for lack of experimental proof; however, the possibility of its being true finds support, at least theoretically, in the science of genetics. It is hypothetically possible that factors for both fat and milk production are found in different loci in two strains; and by mating such strains there would be a complementary effect of the factors from both parents.

Linebreeding.[1] Linebreeding is the mating of two animals to concentrate on the qualities of some superior ancestor. As in inbreeding, the two sides of the mating are common in this respect; but linebreeding differs from inbreeding in that the other ancestors of the two animals are more distantly related or unrelated. The linebred animal, therefore, is not referred to merely as being linebred, but linebred to a certain individual, such as a "Linebred Sophie 19th." Linebreeding is practiced with the idea of holding together and getting in as pure a form as possible the desirable traits of either a superior sire or dam. It has definite limitations in that linebreeding cannot be carried on to one individual for many generations without also involving linebreeding to other descendants of the original ancestor. When this stage is reached, the system changes from that of linebreeding to inbreeding. As contrasted to outcrossing, linebreeding reduces the number of ancestors, but not so much as does inbreeding. Linebreeding with a reasonable amount of selection naturally tends to increase the uniformity of the herd, although not so rapidly, perhaps, as does inbreeding. By linebreeding one avoids, to a certain extent, a good many of the disastrous results encountered in inbreeding, such as loss of fertility and vigor. It is largely through linebreeding that families are established.

Inbreeding. Inbreeding is a system of mating closely related animals, such as brother and sister, son and dam, or sire and daughter. Two purposes may be accomplished by this system of breeding. One is to test the

[1] LUSH. Ia. Agr. Expt. Sta. Bul. 301. 1933.

genetic makeup of the parents, and the other is to produce a more uniform herd by limiting the factors to those within a family.

As has been previously indicated, it is desirable to test the genetic makeup of the parents, and one of the most effective ways of doing this is through backcrossing the offspring to the parents. This is particularly important to the breeder of purebred cattle who is desirous of eliminating from his strain undesirable recessive characters. Animals that are found to have undesirable recessive characters may then be eliminated.

The breeder who has unusually superior stock with characters that he is very desirous of perpetuating and has difficulty in finding nonrelated stock of equal merit, can best perpetuate what he is working for through inbreeding. Frequently, too, a sire has proved to be unusually superior and rather than let his qualities be lost when he can no longer be used for general service, it may be advisable to breed him to his daughters, thus practicing inbreeding.

Inbreeding is not to be recommended to the inexperienced breeder. Merely to inbreed, even when relatively superior animals are used, does not guarantee establishment of uniformity. In order to improve upon a herd by inbreeding, the breeder must follow a plan of rigorous selection to eliminate those individuals possessing undesirable characters.

Dangers of inbreeding. Inbreeding as a general system to be used by the average cattle breeder is fraught with a great many dangers. Inbreeding for a considerable length of time invariably results in loss of vigor, size, and fertility. If there are any lethal or sublethal factors present, the losses will be heavy when inbreeding is practiced. Plant breeders have experienced the same difficulties in the inbreeding of corn; but by crossing two simultaneously inbred lines they have found that vigor is restored, and if proper selection has been made in inbreeding, a superior line is frequently established. While many breeders have noted the deterioration of their inbred lines, there is no record of anyone having practiced inbreeding of two lines of dairy cattle simultaneously and then crossing them.

The United States Department of Agriculture [1] furnishes one of the best examples of the results from inbreeding where daughters from grade cows of average production were inbred to good purebred sires of the Holstein and Guernsey breeds. Inbreeding Guernseys for two generations resulted in lower birth weight of the calves, increase in the incidents of deformity of the calves, and a decrease in the mature weight of the inbred animals. The milk production level of the 50 and 75 per cent inbred daughters was about the same as that of the foundation cows, but the butterfat production was increased with the inbreeding because of an increase in the fat percentage of the milk. The variability of the inbred animals for both milk and fat production was lessened with the degree of inbreeding. For the Holsteins there was no decrease in fertility, but there was a marked decrease in the birth weight of calves with the intensity of inbreeding. The calf mortality increased, and the rate of growth was

[1] Woodward and Graves. U. S. Dept. Agr. Tech. Bul. 927. 1946

slower, resulting in the mature inbred cows being smaller than their foundation cows. The milk production increased and the per cent butter production decreased—the opposite of what happened in the inbreeding of Guernseys. As with the inbred Guernsey, the variability decreased among the inbred Holsteins.

Measures of inbreeding. There are definite formulae for measuring the amount of inbreeding, which is ultimately expressed in per cent. The formula advanced by Sewall Wright [1] is:

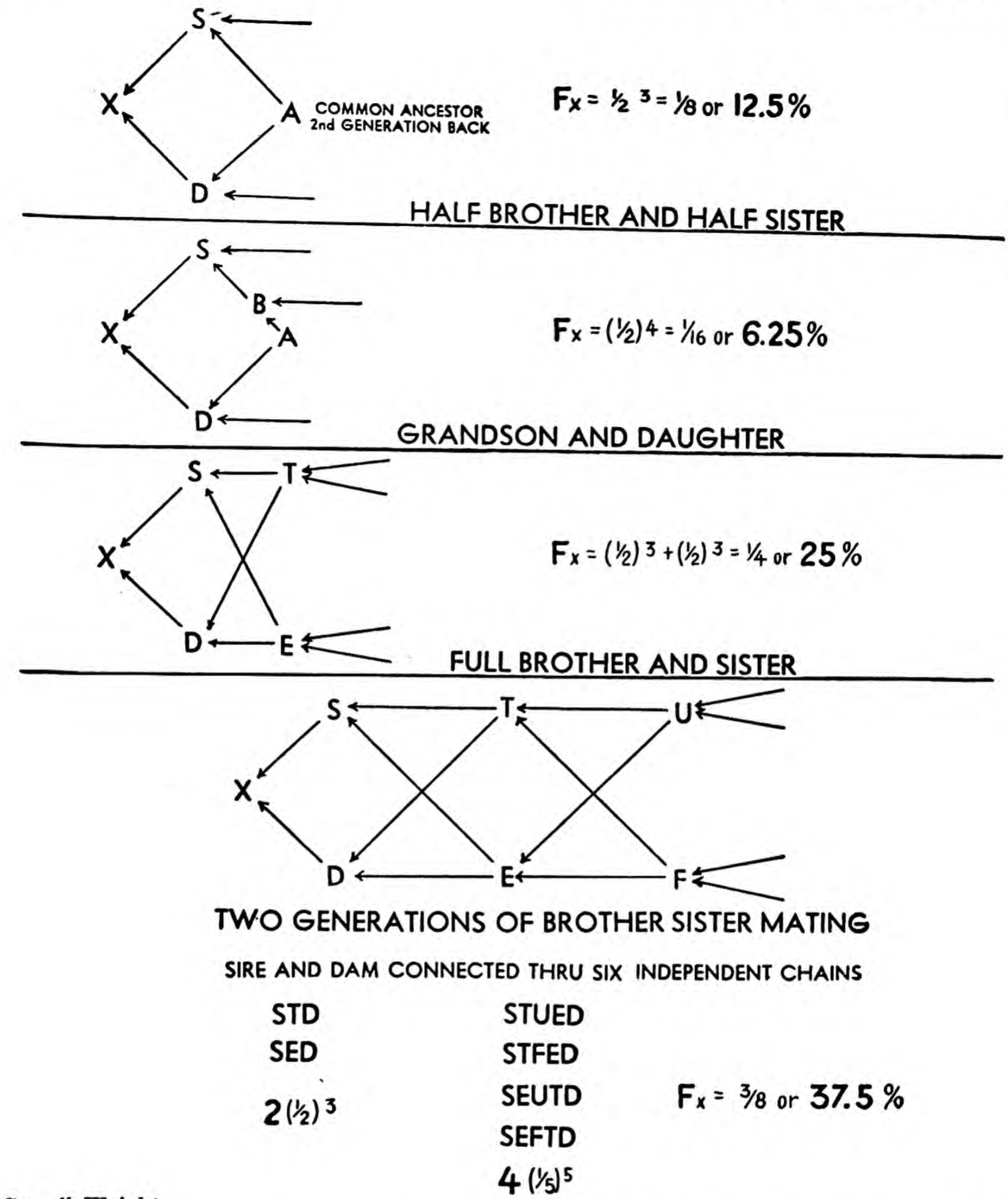
$$F_x = \left((\tfrac{1}{2})^{n + n' + 1} (1 + F_a) \right)$$

F_x represents the coefficient of inbreeding of the individual, n equals the number of generations from the sire, n′ is the number of generations from the dam to the common ancestor, and F_a represents the inbreeding of the common ancestor. Figure 50 illustrates the method of calculating the coefficients of inbreeding for different matings. The coefficient of inbreeding for three generations of brother and sister mating equals 50 per cent. This means that such an inbred animal is 50 per cent less heterozygous than the original parent stock.

Grading up. Grading up is the successive use of purebred bulls of a certain breed on nonpurebred herds. Assuming that the original cows are a different breed than that of the bull, the first cross would have 50 per cent of the inheritance of the breed of the bull; for the second cross this would rise to 75 per cent, and for the third cross to 87½ per cent. Each additional cross would approach toward 100 by one-half of the previous increment. After the fourth or fifth cross, the grades would have most of the characters of the breed which the bull represents, and from many standpoints would be almost as good. While the purity of the breed is closely approximated, grades cannot be registered. There are good reasons for the undesirability of registering grades that theoretically are almost 100 per cent purebred. A grade would be likely to carry many undesirable recessive characters that would appear in mating *inter se*. The difficulty of ridding a breed of a single undesirable recessive character is well known to the breeders of Holsteins, where the red recessive crops out relatively frequently in spite of many years of breeding and selection for black and white. With the intermating of grades, no matter how "high," there would be many similar characters. There have been many successes in developing grade herds of high production and excellent type from scrubs or nondescripts by the use of two or more successive purebred bulls. Specific examples of such accomplishments are given in the next chapter. In the grading-up program the greatest increases in production are noted in the first cross. As the average production of the herd increases, further improvement in production becomes increasingly difficult.

Methods used by noted breeders. Toward the end of the eighteenth century and the beginning of the nineteenth century there was a great

[1] Jour. Hered. 14: 339–422. 1923.



Sewall Wright

Fig. 56. Diagrammatic representation of inbreeding for various related matings.

movement in England for the improvement of cattle, particularly Shorthorns, that resulted in outstanding accomplishments by a number of men who now are recognized as some of the greatest breeders of all times. The Colling Brothers, who started their breeding operations about 1780, Booth, who began to breed Shorthorns about 1790, and Amos Cruickshank, who developed the famous Scotch type of Shorthorns beginning in 1837, are a few of the very outstanding breeders who were credited with the development of the beef characteristics of the modern Shorthorn breed. Thomas Bates, who began breeding Shorthorns just before the

beginning of the nineteenth century and selecting for dairy capacities, used methods similar to those of the other breeders; his methods are of more interest, however, to students of dairying.

Bates is credited with establishing the milking strain of Shorthorns. He first selected individuals with superior dairy characteristics and mated them. These matings were followed by inbreeding, and it was through his intensive inbreeding program that Bates succeeded in fixing the dairy characteristics in the Shorthorn breed that are manifest to this time. He experienced many of the disappointments in inbreeding that are usually encountered. Some of his inbred animals became sterile, and there was a marked loss in vigor. Both of these faults were overcome, however, by judicious outcrossing of carefully selected animals for the characters he was attempting to establish.

Outstanding breeders in other breeds of cattle have practiced very much the same methods. Their successes have not been so outstanding, because they began with a better developed foundation stock than did early English breeders. It is much more difficult to achieve marked improvement with our modern well-developed breeds of cattle than it was a hundred or more years ago when cattle were not so well developed. While these earlier breeders knew nothing of the science of genetics, their practices are certainly supported by the facts made known by genetics.

Modern breeding. At this point we are ready to consider the methods of breeding that should be followed in the improvement of the various herds and breeds of cattle. While there has been a marked improvement in all the breeds of dairy cattle, there is still much room for improvement. In general it can be said that to improve herds of today, the same methods should be practiced that the old master breeders used. One of the major contributions of the science of genetics is the lending of support to the soundness of the methods used by the old breeders. The modern breeder has a big advantage over the older breeders, in that more evidence is available to measure the genetic makeup and breeding value of dairy animals. Although there are not nearly enough records, there are infinitely more records of production than there were years ago.

The most essential requisite for more intelligent breeding is the adoption of a sound testing program in which all the offspring of a sire are tested. Without the adoption of such a program the breeder of today cannot hope to make much progress. He must have available these records in order to select his breeding stock intelligently. Then and only then, by using the records as tools in rigorous selection for the characters toward which he wants to breed and by judicious use of inbreeding, linebreeding, and outcrossing, will he be able to formulate a breeding program that will ultimately produce superior strains.

Modern genetics permits a concept of establishing a pure line for high milk and butterfat production. Such individuals would be homozygous for all of their genes affecting milk and butterfat production. When such animals are obtained, nothing but uniformly high production can result from matings *inter se*.

The adoption of this concept of establishing a pure line for high production as a goal is to be recommended to all breeders and research workers as one that is likely to be productive of results. With this as an objective the problem becomes one of setting up a system of breeding that will eliminate the undesirable characters and retain all the desirable characters now in cattle.

Chapter 25

SELECTION AND CARE OF THE HERD SIRE

IMPORTANCE OF THE HERD SIRE. THE SELECTION OF THE HERD SIRE IS by far the most important decision a breeder has to make. While the evidence indicates that the sire and the dam contribute equally to the inheritance of the offspring, the sire has many more offspring than the dam, and therefore his influence from a hereditary standpoint is much greater than that of a cow. The popular statement that "the sire is half of the herd" is correct to the extent that he is the sire for the whole herd. A superior bull can be responsible for a greatly improved herd, while a poor bull can ruin a herd. The variation in the ability of bulls to sire production is well illustrated in the following table.

ANALYSIS OF 1,000 BULLS MATED TO COWS OF VARYING PRODUCTION LEVELS[1]

Number of Sires	Bred to Cows Producing	Per Cent of Sires Increased Production	Per Cent of Sires Decreased Production
10	Under 200 lbs. fat yearly	100	0
142	200 to 300 lbs. fat yearly	86	14
487	300 to 400 lbs. fat yearly	73	27
305	400 to 500 lbs. fat yearly	42	58
47	500 to 600 lbs. fat yearly	28	72
9	600 to 700 lbs. fat yearly	0	100

This table gives the result of the analysis of 1,000 purebred bulls, showing the per cent of the bulls that increased the average production in herds of various production levels. It will be noted that as the herd averages increase, the percentage of bulls siring daughters superior to their dams in production decreases with the increased average production of the cows to which they are mated. All bulls mated to cows producing less than 200 pounds of fat, sired daughters superior to the cows; and all bulls mated to cows producing more than 600 pounds of fat, sired daughters inferior to their dams. This table also illustrates the increasing difficulty of selecting satisfactory bulls for herds of high producing cows.

Figures from the Grand Rapids, Minnesota, Branch Station not only illustrate what can be accomplished by using good purebred bulls, but also show that improvement is rather rapid from the lower levels of production and much more difficult and slower as the average production

[1] Figures from U. S. Dept. Agr.

of the herd increases. The data presented in the following table represent the increased production by years from scrub cows by the use of purebred Guernsey bulls.

RESULTS FROM USING PUREBRED GUERNSEY BULLS FOR 20 YEARS, BEGINNING WITH COMMON COWS AND GRADING UP [1]

Year	Average Pounds of Milk per Cow	Average Pounds of Butterfat per Cow	Average Per Cent of Butterfat	Average per Herd
1904	4,700	196	4.2	4,700 pounds of milk 196 pounds of butterfat
1911	5,301	226	4.7	
1912	5,371	236	4.4	Six-year average, 1911 to 1916, inclusive:
1913	5,313	227	4.4	
1914	5,519	259	4.7	5,584 pounds of milk
1915	5,721	280	4.9	256 pounds of butterfat
1916	6,281	301	4.8	
1917	7,184	358	5.0	
1918	6,502	313	4.8	Eight-year average, 1917 to 1924, inclusive:
1919	7,152	333	4.7	
1920	6,972	341	4.9	6,968 pounds of milk
1921	6,757	332	4.9	338 pounds of butterfat
1922	6,797	331	4.9	
1923	7,542	362	4.8	
1924	6,841	331	4.8	

Another illustration of what can be accomplished by the use of purebred bulls is furnished by the Iowa Station, where purebred bulls of the Holstein, Guernsey, and Jersey breeds were mated with scrub cows. The results are represented in the next two tables. The first table gives the average production of milk and fat for the original scrub cow and the two succeeding generations. The second table gives the increase in per cent over scrub cows; from this table it can be seen that while there is considerable variability in the degree of increased production, in all cases the production was greatly increased by the use of purebred sires. It may also be added that while the first generation was variable from the standpoint of color and type, the second generation was noticeably of much more uniform type, taking on more of the characteristics of the breed of which the sire was a representative. There are numerous other examples of what has been accomplished through the use of good sires. It must be stated, however, that there are also many examples of the sire having been responsible for great decreases in production, often leading to the ruin of the herd. One bull at the University of Minnesota Station was responsi-

[1] Minn. Agr. Col. Ext. Circ. 15. 1925.

ble for a decrease of 38 per cent in the butterfat production of his daughters as compared with their dams.

RESULTS FROM THE USE OF PUREBRED SIRES FOR TWO GENERATIONS ON SCRUB COWS [1]

GROUP PUREBRED SIRE USED	DAMS		DAUGHTERS		GRANDDAUGHTERS	
	Milk	Fat	Milk	Fat	Milk	Fat
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Holstein.........	3,782	176	6,839	274	11,127	420
Guernsey........	3,687	168	5,102	241	5,810	301
Jersey...........	3,463	168	5,009	264	5,411	287
Average.........	3,660	172	5,999	261	8,402	358

PERCENTAGE OF INCREASE IN PRODUCTION OF THE TWO GENERATIONS OF GRADES OVER THEIR SCRUB DAMS [1]

GROUP	INCREASE IN PRODUCTION			
	First Generation		Second Generation	
	Milk	Fat	Milk	Fat
Holstein............	81%	55%	94%	138%
Guernsey...........	38%	43%	58%	74%
Jersey..............	45%	57%	56%	71%
Average............	64%	52%	130%	109%

Factors to consider in selecting a bull. Bulls may be selected for one or more of the following considerations:

1. Type of the animal.
2. Pedigree.
3. Consideration of progeny performance.

As the fundamentals involved in this have been discussed previously (Chapter 22), only a brief review is necessary here.

Type. Type should be given serious consideration because of the desirability of having a bull of good type and also because type is inherited. Frequently it is the only consideration taken into account in selecting a bull; this cannot be justified. Many bulls of excellent type are sires of offspring that are mediocre in this respect, and no evidence exists that there is any marked correlation between the type of a bull and the production of his daughters.

[1] McCANDLISH, GILETTE, AND KILDEE. Ia. Agr. Expt. Sta. Bul. 188. 1919.

Selection on the basis of type is even less reliable for the young bull, as there may be marked changes in the body conformation with development. A young animal of inferior type may improve with age; and conversely a young bull of good type may become poorer in this respect with increase in age.

The Purebred Dairy Cattle Association has prepared a score card for the dairy bull of all breeds which has the approval of the American Dairy Science Association. That score card with comments on special breed characteristics and evaluation of defects is reproduced here.

Dairy Bull Score Card

Ideals of type and breed characteristics must be considered in the application of the terminology of this score card.

Based on Order of Observation		Perfect Score	Bull Under Observation	Official Score
1. GENERAL APPEARANCE		**30**		
Attractive individuality, revealing vigor, masculinity with a harmonious blending, and correlation of parts. Impressive style and attractive carriage with an active, well-balanced walk.	20			
BREED CHARACTERISTICS (see below)				
HEAD masculine, medium in length, clean-cut; broad muzzle with large open nostrils; lean, strong jaw; full, bright eyes; forehead broad between the eyes and moderately dished; bridge of nose straight; ears medium size and alertly carried.	—			
SHOULDER BLADES set smoothly against chest wall and withers, forming neat junction with the body.				
BACK strong and appearing straight with vertebrae well defined.				
LOIN broad, strong, and nearly level.				
RUMP long, wide; top-line level from loin to and including tail head.	10			
HIPS wide, approximately level laterally with back, free from excess tissue				
THURLS wide apart.				
PINBONES wide apart and slightly lower than hips, well defined.				
TAIL HEAD slightly above and neatly set between pinbones.				
TAIL long and tapering with nicely balanced switch.	—			
2. DAIRY CHARACTER		**35**		
Animation, angularity, general openness, and freedom from excess tissue.				
NECK masculine and long, with moderate crest blending smoothly into shoulders. Clean-cut throat, brisket, and dewlap.				
WITHERS well defined and wedge-shaped with the dorsal processes of the vertebrae rising slightly above the shoulder blades.				
RIBS well arched, wide apart, rib bone flat, wide, and long.				
FLANKS arched and refined.				
THIGHS when viewed from the side, flat; when viewed from the rear, wide apart. Well cut-up between the thighs.	35			
SKIN of medium thickness, loose and pliable. Hair fine.				
TESTICLES both normal. Scrotum normal.				
RUDIMENTARY TEATS wide apart, squarely placed and in front of scrotum.				
MAMMARY VEINS large, long, and well defined.	—			
3. BODY CAPACITY		**20**		
Relatively large in proportion to size of animal, and deep at the flank, providing ample digestive capacity, strength, and vigor.	10			
BARREL deep, strongly supported, ribs wide apart, and well sprung.				
HEARTGIRTH large, resulting from long, well sprung foreribs, wide chest floor between front legs, and fullness at the point of elbow.	10			
4. LEGS AND FEET		**15**		
FORELEGS medium in length, straight, wide apart, squarely placed. Feet short, and well rounded, with deep heel and level sole.	5			
HIND LEGS when viewed from the side, nearly perpendicular from hock to pastern. When viewed from the rear, legs wide apart and nearly straight. Bone, flat and flinty, tendons well defined. Pasterns, of medium length, strong, and springy. Hocks cleanly moulded. Feet same as above.	10			
TOTAL		**100**		

AYRSHIRE CHARACTERISTICS

Color—Red of any shade, mahogany, brown or these with white, or white, each color clearly defined. Distinctive red and white markings preferable; black or brindle markings strongly objectionable.

Size—A mature bull in breeding condition should weigh about 1,800 pounds.

Horns—Inclining upward, medium size at base, refined, medium length, and tapering toward tips.

GUERNSEY CHARACTERISTICS

Color—A shade of fawn with white markings clearly defined, black or brindle markings objectionable. Skin should show golden yellow pigmentation. When other points are equal, a clear or buff muzzle will be favored over a smoky or black muzzle.

Size—A mature bull in breeding condition should weigh about 1,700 pounds.

Horns—Inclining forward, medium size and yellow at base, refined, medium in length, and tapering toward tips.

JERSEY CHARACTERISTICS

Color—A shade of fawn, with or without white markings.

Size—A mature bull in breeding condition should weigh about 1,500 pounds.

BROWN SWISS CHARACTERISTICS

Strong and vigorous. Size and ruggedness with quality desired. Extreme refinement undesirable.

Color—A shade of brown varying from a silver to a dark brown. Hair inside ears is a lighter color than body. Nose and tongue black with a light colored band around nose. Color markings which bar registry are: white switch, white on sides, top, head or neck and legs above knees or hocks. White on belly or lower legs objectionable.

Size—A mature bull in breeding condition should weigh about 1,900 pounds.

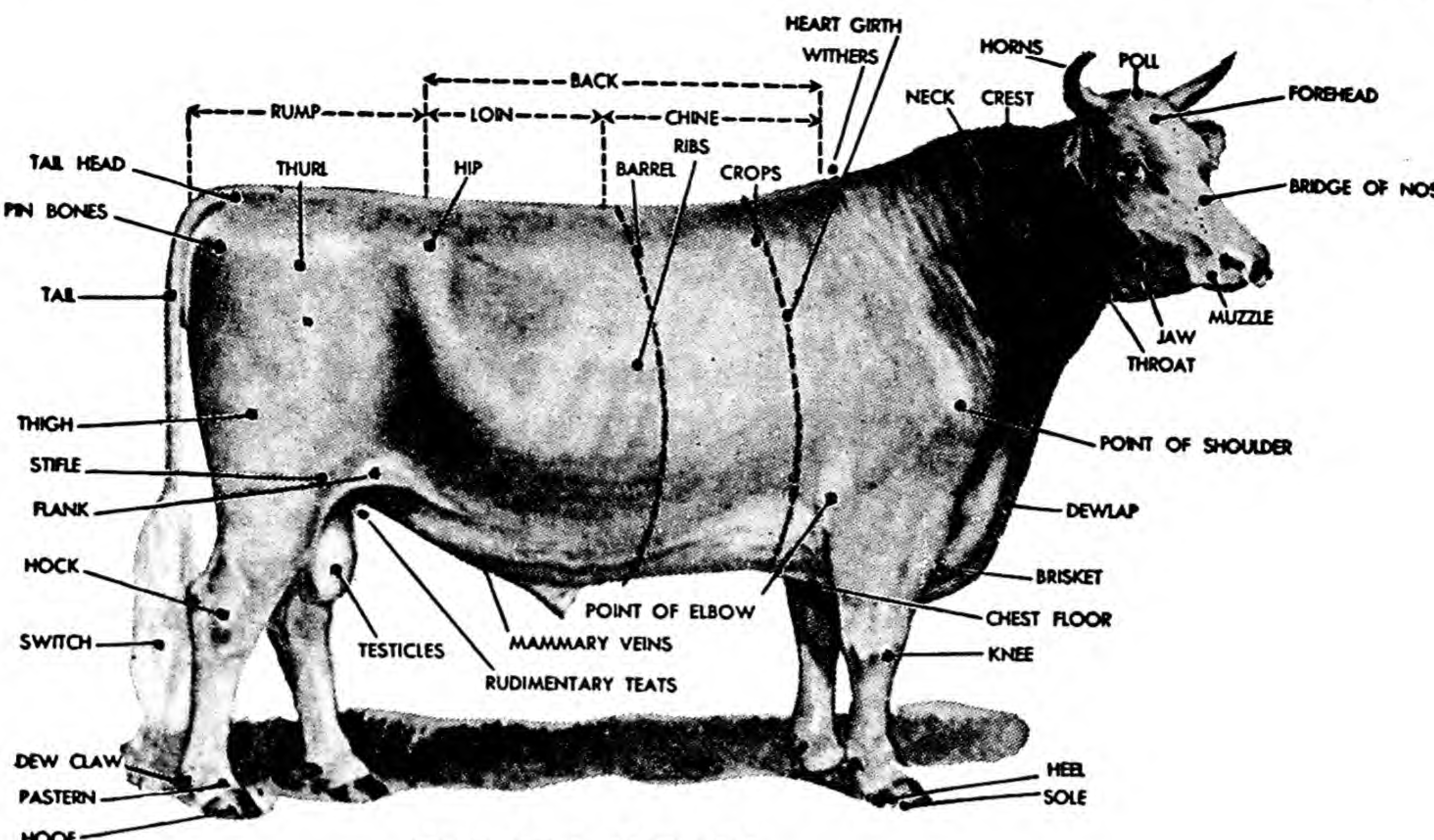
Horns—Inclining forward and slightly up. Medium size at base, medium length, tapering toward black tips.

HOLSTEIN CHARACTERISTICS

Color—Black and white markings clearly defined. Color markings which bar registry are solid black, solid white, black in switch, black belly, black encircling leg touching hoof, black from hoof to knee or hock, black and white intermixed to give color other than distinct black and white.

Size—A mature bull in breeding condition should weigh about 2,000 pounds.

Horns—Inclining forward, incurving, medium size at base, refined, medium length and tapering toward tips.



PARTS OF A DAIRY BULL

Fig. 57. Parts of the dairy bull are pictured above.

Pedigree. The value of a pedigree as an instrument in evaluating dairy animals has been described previously. It was pointed out that the pedigree containing ample information about the ancestors and close relations of an animal is of great value in evaluating such an animal. Most pedigrees, however, do not contain sufficient information, either because much of the information that is needed is left out by the pedigree writer or because not enough of the ancestors have production records. The breeder who follows out a certain line of breeding finds additional value in the pedigree. For commercial reasons breeders often find it advantageous to follow certain lines of breeding that have been publicized and come into popular demand. Following such lines in a breeding program facilitates sale of surplus stock at better prices. While in some cases it is unfortunate that such a situation should exist in that it may interfere with a constructive breeding program, nevertheless it is a reality that must be recognized. For the most intelligent selection the pedigree must always be taken into account. If it contains a complete record of all the necessary information about the ancestors and close relations, it can be an instrument that is reasonably accurate in the evaluation of the bull. Its use merely to follow certain blood lines, however, contributes very little to a constructive breeding program.

Progeny performance. Evaluating animals on the basis of progeny performance is the most reliable of any method that is available to the breeders of dairy cattle. The fundamentals to be considered in selecting and evaluating upon the basis of the progeny performance have been fully discussed previously. While it is generally recognized that if a bull has sired progeny of the desired characters in one herd he will do so in

EVALUATION OF DEFECTS

In a show ring, disqualification means that the animal is not eligible to win a prize. Any disqualified animal is not eligible to be shown in the group classes. In slight to serious discrimination, the degree of seriousness shall be determined by the judge.

EYES

1. Total Blindness: *Disqualification.*
2. Blindness in one eye: *Slight discrimination.*
3. Evidence of arthritis, crampy hind leg: *Serious discrimination.*
4. Enlarged knees: *Slight discrimination.*

WRY FACE

Serious discrimination.

PARROT JAW

Serious discrimination.

SHOULDERS

Winged: *Serious discrimination.*

CAPPED HIP

Slight discrimination.

TAIL SETTING

Wry tail or other abnormal tail settings: *Slight to serious discrimination.*

LEGS AND FEET

1. Lameness—apparently permanent and interfering with normal function: *Disqualification.*
   —apparently temporary and not affecting normal function: *Slight discrimination.*
2. Bucked knees, blemished hocks, crooked hind legs, weak pasterns: *Serious discrimination.*

ABSENCE OF HORNS

No discrimination.

LACK OF SIZE

Slight to serious discrimination.

TESTICLES

Bull with one testicle or with abnormal testicles: *Disqualification.*

OVERCONDITIONED

Serious discrimination.

TEMPORARY OR MINOR INJURIES

Blemishes or injuries of a temporary character not affecting animal's usefulness: *Slight discrimination.*

EVIDENCE OF SHARP PRACTICE

Animals showing signs of having been operated upon or tampered with for the purpose of concealing faults in conformation, or with intent to deceive relative to the animal's soundness: *Disqualification.*

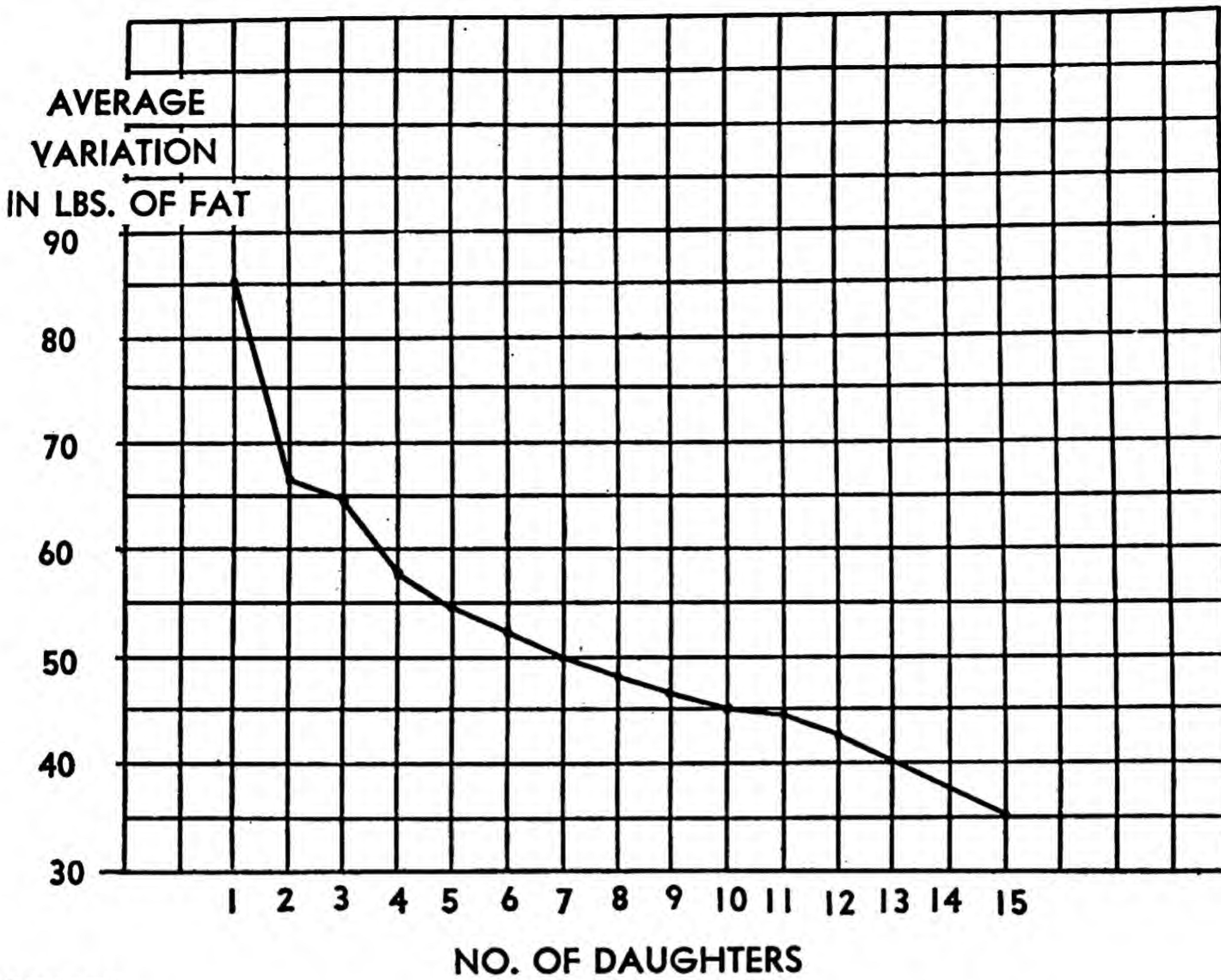
another, it is not always assured. The exceptions, however, are so infrequent that they do not deter materially from the desirability of using sires proved on the basis of their progeny performance. This consideration is so important that further attention is given under the following heading.

Proven sire. A proven sire is a sire having daughters with production records from dams with production records. The question as to the number of tested daughters that a sire needs in order to be proven is as yet somewhat controversial. Various arbitrary numbers of daughter-dam pairs that are needed to pronounce a bull as being proven have been suggested. Davidson published data that indicated that the first six daughters are the smallest number that could be used as being reasonably reliable in indicating the production the bull will sire.[1] Guiford, however, indicates 10 pairs as the least number from which the average production of future progeny can be predicted with reasonable reliability. Copeland has studied this problem by working the coefficients of correlation between different numbers of daughter-dam pairs with the average yields of all subsequent daughters.[2] His results are presented graphically in Figure 58. The predictions based upon 6 daughter-dam pairs were found to deviate by more than 50 pounds of fat from the actual average production of subsequent daughters. When 10 pairs were used, the deviation dropped to 45 pounds; and when 15 pairs were used, it dropped to 35 pounds.

A striking example of what good proven sires will accomplish is furnished by the following table [3] in which the performance of 426 proven

Butterfat Production Range of Dams (Pounds)	Sires	Sires That		Average Production of				Increase (+) or Decrease (−) by Daughters	
		Maintained or Increased Production	Decreased Production	Dams		Daughters			
				Milk	Butterfat	Milk	Butterfat	Milk	Butterfat
	Number	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
250–274	1	1	0	5,341	268	6,540	343	+1,199	+75
275–299	4	4	0	6,967	287	8,436	362	+1,469	+75
300–324	15	15	0	7,072	313	8,012	372	+940	+59
325–349	15	13	2	7,460	339	8,586	393	+1,126	+54
350–374	69	57	12	8,776	359	9,634	400	+858	+41
375–399	85	62	23	9,703	388	10,172	420	+469	+32
400–424	95	70	25	10,355	411	10,809	436	+454	+25
425–449	63	40	23	10,792	437	10,933	452	+141	+15
450–474	37	27	10	11,814	457	12,054	471	+240	+14
475–499	26	13	13	12,328	485	11,941	474	−387	−11
500–524	14	6	8	13,919	511	13,504	506	−415	−5
550–574	2	0	2	15,387	552	12,864	482	−2,523	−70
Total or Average	426	308	118	10,161	407	10,576	433	+415	+26

[1] Davidson. Ill. Agr. Expt. Sta. Bul. 270. 1925.
[2] Copeland. Jersey Bulletin 51:8. Jan., 1932.
[3] U.S.D.A., D.H.I.A. Letter Vol. 24, No. 6, 1948.



Copeland

Fig. 58. Graphic presentation of the variation (in pounds of butterfat) of each group of daughters of a bull from 1 to 15—from the average of all daughters.

sires used in artificial breeding associations on January 1, 1948 are analyzed.

Objections to the proven sire. While a proven sire is the best insurance that a breeder can have as to how a bull will perform, there are several factors to be considered that are not so favorable to the use of a proven bull. The first, as has already been intimated, is that there is difficulty in properly evaluating the proven bull. A second and more serious one, is that proven bulls are scarce and frequently impossible to find. Then, too, the value of the proven bull is likely to be fully realized by the owner, and the price, therefore, is likely to be too high. Of necessity, the proven bull is considerably advanced in age; and the risk of losing his services because of sterility, death, or injury is great. Many breeders prefer to use younger bulls because there is less danger of their being vicious. The old bull, if he has such tendencies, has had them fully developed when he arrives at the age that he is proven. The latter reason should not be given serious consideration and should not be a deciding factor if the equipment for handling the bull on the farm is adequate.

Bull association. Bull associations, for some reason, have not been very popular in the United States. Since the first was organized in 1908, the growth in numbers has been slow and disappointing. In Denmark, where probably the most rapid development in dairy cattle has taken place most of the breeders of cattle were members of bull associations and now of artificial breeding associations. In 1936 there were 243 bull associations in the United States.[1] In 1947 this number had dropped to 140, with 23,519 cows. A bull association is an organization formed by breeders of cattle who jointly buy a number of bulls. The association is divided into several blocks with one or more breeders to a block. The association purchases, as a whole, enough bulls so that there is one for each block. After a period of about two years, these bulls are moved; in another two years, they are again moved; and so on, until they have made a circuit or have been put out of service for some reason or other. The advantages of a bull association are self-apparent. First, by pooling the resources of a large number of breeders better bulls can be purchased. Second, it permits buying bulls to promote a definite breeding program. Third, it reduces the cost of bulls, inasmuch as they are used for a longer period of time than would otherwise be the case. Fourth, and perhaps the most important of all advantages, is that it necessitates the keeping of a bull until he is proven. If a bull is found to be an unusually superior sire, there is usually provision made that his services will be available to all members. Fifth, because of the business organization essential for the promotion of a bull association, it arouses an enthusiasm which is reflected in better business management of the herd in general. Provisions are also made that if a bull should prove to be unsatisfactory, he is immediately sold and replaced by another one. In this way the members of a bull association have the best guarantee possible of having only desirable bulls.

Feeding the bull. The object in feeding a young dairy bull is to grow him into a healthy, vigorous animal at a rate that will bring him to service at as early a date as possible. A bull calf should be fed in the same way as the heifer calf (see Chapter 30), except that in some cases he should be fed more liberally in order to grow him into size for early service. The amount of feed to be given a mature bull should be gauged by his condition. He should be kept in a vigorous physical condition, but not too fat, as too much fat has a tendency to make him sluggish. The Minnesota Station reported on the amount of feed required to keep service bulls in a satisfactory condition. They called attention to the fact that the amount of nutrients required to keep the bull in the desired condition approximated very closely the nutrients required for maintenance. The daily rations for the bulls are set forth in the table on page 249.

It will be noted that from 4.5 pounds to 5 pounds of grain were allowed daily and that the amount of silage was limited to no more than the amount of hay fed. The mature bull could probably secure the necessary nutrients from roughage, but in so doing, he would develop too large a

[1] U. S. Dept. Agr. Agricultural Statistics. 1936.

paunch. While there is no evidence that silage is harmful, it is advisable to limit the amount fed to not over 15 pounds daily. The hay preferably should be a good grade of legume, such as alfalfa or the clovers. When the hay consists of a legume, a satisfactory grain mixture consists of 200 parts of oats, 100 parts of barley, and 100 parts of corn. When the roughage is of the low protein type, such as timothy or prairie hay, 75 pounds of linseed oil meal or some other similar high protein concentrate should be added to each 200 pounds of the aforementioned grain mixture. During the summer it is advisable to furnish the bull with a limited amount of pasture or some soilage crop. While there is no positive evidence that the furnishing of green feed is absolutely necessary, it is possible that the bull may benefit from the vitamins that are present in all green feeds.

For bulls in artificial insemination service, workers at Cornell University [1] are recommending somewhat heavier feeding. They have formulated a tentative feeding standard for bulls in this service in which 40 per cent of the T.D.N. is supplied in grain and 60 per cent in hay. The table on page 250 gives the requirements for bulls ranging from 1,200 to 2,600 pounds.

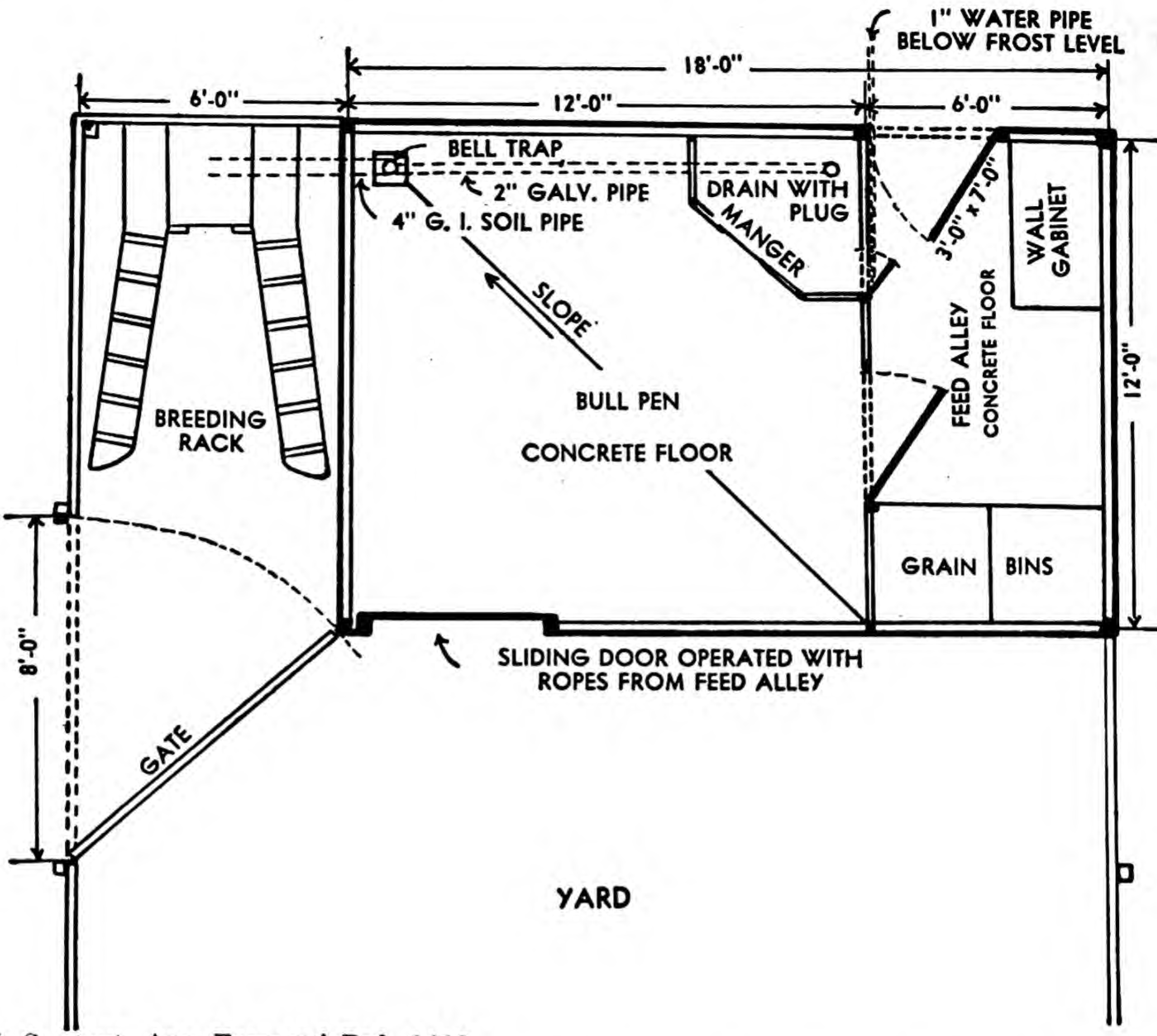
DAILY RATIONS FOUND ADEQUATE FOR SERVICE BULLS AT THE UNIVERSITY OF MINNESOTA [2]

Cattle	Alfalfa Hay	Corn Silage	Grain
	Pounds	*Pounds*	*Pounds*
Winter:			
Jerseys	12	8	4.5
Holsteins	18	14	5.0
Ayrshires	16	12	5.0
Summer:			
Jerseys	12	5	5.0
Holsteins	14	13	5.0
Ayrshires	12	12	5.0

Housing and yard. Although it is not necessary to furnish the herd sire with as warm a house as it required for the milking cow, he should be given housing conditions that will protect him from exposure to the elements. The house and the yard for the bull must be considered together, for they should be arranged to facilitate the handling of unruly bulls and to afford opportunity for daily exercise in the yard. The bull may be housed either in a small house by himself or occupy a box stall in a portion of the barn. In either event there should be access directly to a yard through a door that is operated by controls from outside the pen. The box stall or pen should be 12 feet square. The general scheme of a satisfactory arrangement of both the pen and the yard is presented in Figure 59.

Attention is directed to the arrangement of the manager in a corner of the pen, to the door operated by cord which opens into the yard, and to

[1] BRANTON, BRATTON AND SALISBURY. Jour. Dairy Sci. 30:1003, 1947
[2] SCHAEFER AND ECKLES. Jour. Dairy Sci. 12: 165–173.



U. S. Dept. Agr. Farmers' Bul. 1412

Fig. 59. Plan for an ideal bull pen with yard and breeding rack arrangements.

TENTATIVE FEEDING STANDARD FOR DAIRY BULLS

Body Weight *Pounds*	Total Digestible Nutrients Required Per Bull Per Day	Pounds of 75 Per Cent T.D.N. Concentrate to Supply 40 Per Cent of T.D.N.	Pounds of 50 Per Cent T.D.N. Hay to Supply 60 Per Cent T.D.N. Requirements
1,200	10.27	5.5	12.3
1,300	10.93	5.8	13.1
1,400	11.59	6.2	13.9
1,500	12.25	6.5	14.7
1,600	12.91	6.9	15.5
1,700	13.57	7.2	16.3
1,800	14.23	7.6	17.1
1,900	14.89	7.9	17.9
2,000	15.56	8.3	18.7
2,100	16.22	8.6	19.5
2,200	16.88	9.0	20.3
2,300	17.54	9.4	21.0
2,400	18.20	9.7	21.8
2,500	18.86	10.1	22.6
2,600	19.52	10.4	23.4

the breeding rack with gate arrangements in the yard. The pen is designed so that there will be no need of handling the bull, thereby insuring the maximum of safety. In the care of the pen one of the important considerations is to keep it well bedded during the cold weather to prevent the bull from contracting arthritis, a disease which frequently affects and impairs the use of a bull. While a bull yard is to be preferred over anything else for a place in which the bull may exercise, a fairly satisfactory substitute may be constructed by suspending a stout cable 75 to 100 feet in length, to which the bull may be tied by means of a ring and a swivel joint. By this arrangement he can travel along the entire length of the cable. If one end of the cable is fastened to the barn, it is possible for the bull to go in or out of his pen without being untied.

Cost of keeping the herd sire.[1] The cost of maintaining a herd bull varies with different conditions. The more important items to be considered are the costs of feed, bedding, housing, veterinary service, and labor. In addition to this the interest on investment and depreciation in value must be added.

The feed costs for a service bull, which vary greatly, depend upon the size of the bull and the price of the feeds. The larger bulls consume more feed than smaller ones. This is illustrated in the following table,[2] which

AMOUNT OF FEED REQUIRED AND COST OF KEEPING A HERD SIRE [2]

	Holstein Bull Weighing 2,500 Lbs.		Jersey Bull Weighing 1,800 Lbs.	
	Amount	Value	Amount	Value
Hay at $15.00 per ton	7,500 lbs.	$ 56.25	5,400 lbs.	$ 40.50
Grain at $25.00	2,000 lbs.	25.00	1,500 lbs.	18.75
Housing, bedding, etc.		22.80		22.80
Labor at 25 cts. per hr.		6.75		6.75
Total		$110.75		$ 88.80
Interest on investment, 5% on $100.00		$ 5.00		$ 5.00
Depreciation:				
When used only 2 years		12.50		23.00
When used 4 years		6.25		11.50

compares the amount of feed consumed by a Holstein bull weighing 2,500 pounds and a Jersey bull weighing 1,800 pounds.

The hay consumed by a bull in a year approximates three times his weight, and in addition to the hay 1,500 to 2,000 pounds of grain should

[1] U. S. Dept. Agr., Bur. Dairying, Circ. 3.
DAWSON. U. S. Dept. Agr. Farmers' Bul. 1412.

[2] U. S. Dept. Agr., Bur. Dairying, Circ. 3.

be allowed. If silage is fed, three pounds of silage replaces one pound of hay. Thus, three tons of silage would replace one ton of hay.

The costs of housing, bedding, veterinary service, etc. again would vary, and only average figures can be given. According to the United States Department of Agriculture, these costs average $22.80 annually.[1] The same source is responsible for the statement that 27 hours of man labor is required annually to care for the bull. The total cost for the Holstein bull referred to above is $110.75 and for the Jersey $88.80 when hay is valued at $15.00 per ton, grain at $25.00 per ton, and labor at 25 cents per hour.

In addition to these costs, charges for interest on the investment and depreciation must also be made. If the bull costs $100.00, there is an annual charge of $5.00 for interest on the investment; and if the bull is used two years and is then sold for beef at three cents a pound, there must be an annual charge of depreciation of $12.50 for the Holstein and $23.00 for the Jersey. If the bull is used four years the annual depreciation charge becomes one-half of that when he is used only two years. It is apparent that the higher the original cost of a bull, the greater will be the annual depreciation charges.

Handling the bull. The dairy bull is a potential killer, and should be handled with that fact constantly in mind. One should never place himself in a disadvantageous position with a bull, even if the bull is apparently gentle. Many people have been killed or injured when they have gone into the pen or yard with a bull that was thought to be gentle, but that suddenly turned vicious. Before one enters the pen, care should be taken to see that the bull is securely fastened. Bulls a year old or over should never be handled except with a staff, unless there are two or more attendants, each with a rope from the halter, on either side of the bull. A bull should never be teased or played with. He should be handled firmly at all times. Never should he be put in a position where he is forced to test his strength; for on so doing, he will discover his great power, and from that time on will be exceedingly hard to manage. If an especially vicious bull is to be moved from one place to another, extra precautions should be taken. One of the safest ways of handling a bull is to hobble him. This is done by the following method: A band or rope is placed around his chest, with a ring or loop on either side of the body. Through each loop is passed a rope which is fastened to the corresponding forefoot. These ropes extend to the posterior, where each is manipulated by an attendant. When the bull becomes unruly, traction on the rope brings him to his knees. Some people believe this method to be the best way of taming vicious bulls.

Ringing.[2] Regardless of how easily a bull may be handled, he should have a ring inserted in his nose. It is a good plan to insert a ring at an early age (from six to eight months) in order that he may become accustomed to being handled by the ring. At this time a small ring two to two

[1] BAIN. U. S. Dept. Agr. Buls. 858, 919, 923, 955.
[2] U. S. Dept. Agr., Farmers' Bul. 1412.

and one-fourth inches in diameter should be inserted; this is replaced by a larger ring at the age of 20 months to two years of age. The ring is inserted in the septum of the nose, in an opening made with a trocar and cannula. When it becomes necessary to replace the smaller ring with a larger one, it is usually not necessary to enlarge the opening in the septum. Occasionally the nose is torn out; then it becomes necessary to insert the rings vertically through the upper portion of the nose, or to use special halters that are made for the handling of vicious bulls.

Trimming the feet. Because the bull is confined to a relatively small yard, his hoofs grow much more rapidly than they are worn off. Unless they are trimmed, the hoofs become so long that, in addition to being unsightly, they are painful to the animal, producing lameness by creating tension on the muscles and tendons. At least once (better, twice) a year the hoofs should be trimmed. For this the bull is cast or put in stocks. A pair of pinchers may be used in clipping off the toes; this is followed by the use of a rasp to smooth down the surface. If the yard in which the bull exercises is covered with cinders or gravel, the hoofs may be worn down sufficiently to avoid the necessity of trimming.

Dehorning. While heifers should be dehorned when they are two or three days old, it is not advisable to dehorn the bull at this time for two reasons: (1) If he is to be sold, lack of horns may detract from his sales value. (2) It is considered a good plan to let the bull develop horns and find out how to use them before dehorning him. Then when the horns are removed, the bull will be somewhat at a loss as to what to do. This may be one way of taking the meanness out of a vicious bull. It is preferable to saw the horns off when he is about 18 months to two years of age. Details of dehorning cows are treated in Chapter 34; these also hold for the bull.

Exercising. Unless the bull gets sufficient exercise, he is likely to become impotent. This is particularly true for older bulls. On the average dairy farm the question of exercising the bull is a problem of no small importance. The first requisite for exercise is a yard of sufficient size. However, even with a bull yard, many bulls refuse to exercise of their own accord. It then becomes necessary to furnish some contrivance to force exercise. Some of the several means that have been resorted to are:

1. Suspending a block of wood by means of a chain from a cross bar. Some bulls take delight in playing with this for hours at a time, thus getting the necessary exercise.
2. Chaining a strong barrel or similar solid object to the ground in the middle of the lot. Most bulls take pleasure in rolling a barrel or other object around the lot, and the chain prevents it from being pushed into the lot corner, from which the bull would be unable to remove it.
3. Training the bull to work in a yoke, thus making use of his power for productive work. Inasmuch as considerable difficulty is experienced in training him and as he is never to be entirely trusted, this way of exercising the herd sire is not very popular.
4. Using the treadmill. Here, too, the bull might produce power for use in grinding feed or pumping water. This means is objected to because con-

siderable labor is involved in bringing the bull to and from the treadmill, and because most bulls soon learn how to rest on the treadmill.

5. Placing two or more bulls in the same lot. If one is a young bull, this is quite satisfactory, as the young bull is quick enough to avoid injury from the older one. Evenly matched old bulls may seriously injure each other. Frequently fights develop which end in the death of one or more of the contestants.
6. Using a sweep. A large timber is pivoted, and a bull is tied to each end. When one bull moves, the other one is forced to move also. For some time, at least, they usually fail to co-operate, and thus each one stimulates the other into action.
7. Using patented bull exercisers. Recently several patented bull exercising contrivances have appeared on the market. These involve the use of motors as a source of traction to keep the bulls moving during the exercising period.

Service life of a bull. According to Lush the average reproduction life of dairy bulls in registered herds is 2.2 years.[1] This necessitates an annual replacement of 45 per cent of the dairy bulls. This short service period for bulls is accounted for by the sale of the bull to avoid inbreeding, not because of sterility. Copeland studied 288 bulls and found the average age at which service ceased to be nine years and six months.[2] The details as to the number and per cent total that went out of service for each age class are set forth in the following table. Twenty-one or 7.3 per cent of the 288 bulls were in service at 14 years of age, while 27 or 9.4 per cent went out of service before five years of age.

Age of the bull and quality of offspring. The age of neither the sire nor the dam has any influence upon the quality of the offspring. This is contrary to the belief of some people who hold that the progeny from older parents are superior to those from younger parents. The germ plasm is set aside early in the embryonic life, and there is no evidence that there is any change in the genetic makeup of the germ plasm with the advancing of age; nor is there any reason to expect that there should be

AGES AT WHICH 288 PUREBRED BULLS WENT OUT OF SERVICE

Age at Last Service	Number of Bulls	Per Cent
Under 5	27	9.38
5 to 6	18	6.25
6 to 7	23	7.99
7 to 8	18	6.25
8 to 9	29	10.07
9 to 10	39	13.54
10 to 11	40	13.89
11 to 12	26	9.03
12 to 13	20	6.94
13 to 14	27	9.38
Over 14	21	7.29
Total	288	

[1] LUSH. Ia. Agr. Expt. Sta. Bul. 290. 1932.
[2] Jersey Bulletin, p. 871. May 22, 1929.

any change. Some credence has been given to the assertion that older bulls sire superior offspring. When, as frequently happens, a meritorious bull finds his way into better herds and is mated to superior cows, the offspring from such matings are naturally superior to his previous offspring; this is the only basis for the assertion.

Service. Well-grown bull calves may be ready for light service when ten to twelve months of age. At two years of age, a bull has reached the maximum of his breeding powers; this is maintained until he is about six years of age. After six years of age there is a decline in the breeding powers, so that after eight years of age many bulls are slow and uncertain as breeders. Many bulls however, continue to be excellent breeders up to twelve to sixteen years of age. A bull should not be permitted to serve more than one or two cows a week until he is fifteen months of age. The number of services may then be increased so that at two years of age, five services per week may be permitted. As in most dairies the breeding is confined to a short season, a bull can serve for only 50 or 60 cows. After six years of age, the number of services per week should be reduced with advance in age. A breeding rack should be used when large bulls are bred to young heifers, as otherwise the heifer may suffer injury. When young bulls are mated to large cows, the service may be facilitated by standing the cow in a shallow pit.

Sterility. Sterility in the bull may seriously affect the breeding program of a herd. It usually requires several months to ascertain whether or not a bull is sterile; and after that some time is needed to acquire another bull. As a result the breeding of some cows may be delayed six months or more. This entails not only a loss in milk production but a disruption of the plans for seasonal freshening of the cows.

There are many causes for sterility and little known about treatment that is effective. In some cases due to inheritance the bulls may be sterile from the beginning or become sterile while still young. Other cases are caused by disease and others by overuse. The part that nutrition plays is not understood. From available experimental data, it would seem that deficiencies in nutrition must be rather extreme to produce sterility.

Low ascorbic acid content of the blood is associated with some cases of sterility but not related to the diet. Sterility due to this cause may be corrected by the subcutaneous administration [1] every three or four days of one gram of ascorbic acid dissolved in 5 cc. of sterile saline solution per 1,000 pounds live weight. Feeding of ascorbic acid is ineffective, since this vitamin is destroyed in the digestive tract. The ascorbic acid solution should be made up fresh before each injection.

Exercise is considered essential for maintenance of good fertility although experimental evidence for this belief is still lacking.

[1] PHILLIPS. Jour. Am. Vet. Med. Assoc. 97:165. 1940.

Chapter 26

ARTIFICIAL INSEMINATION

WITH THE INTRODUCTION AND RAPID DEVELOPMENT OF ARTIFICIAL INsemination the dairy industry has acquired a tool that will rank without equal in improving dairy cattle. While there is still much to learn about the various aspects of this new device, sufficient is known to make it an established and well accepted institution. No other innovation in the dairy world has developed as rapidly or met with as wide acceptance. Virtually a new science has developed this innovation, dealing with the techniques involved in getting, handling, and storing of the semen; selection and care of suitable bulls; insemination of cows, and the many problems incident to the organization and operation of artificial insemination societies.

Historical. The technique of inseminating by artificial means is not new. The Arabs are reported to have artificially inseminated mares six centuries ago and for more than 150 years it has been generally known that the introduction of semen into the reproductive tract at the right time will produce conception in many species.

The idea of using artificial insemination extensively in the breeding of dairy cattle, however, is of recent origin. The Russians are credited with developing the practical aspects, based upon the discovery that semen may be preserved by cooling it. This work began in Russia about 1909, when certain studs used artificial insemination in practice. Beginning about 1923, this method of breeding became more widespread and by 1938, about 1,500,000 cattle, approximately 5 per cent of all cattle in Russia, were artificially inseminated.

Denmark was the next country to introduce artificial insemination of cattle on a large scale. The work was started in 1936 and by 1947 approximately 50 per cent of the inseminations of cows were artificial. The first artificial insemination society in the United States was organized in New Jersey in 1938 by E. J. Perry following his return from Denmark where he became impressed with the idea of its potentialities. Since that time in spite of the intervening war years, the growth has been steady.

The following table shows the phenomenal growth of artificial insemination societies in the United States.

Year	Bulls in Service	Cows Bred
1939	33	7,539
1941	237	70,751
1943	574	182,524
1945	650	342,012
1946	1453	1,125,040

Advantages of artificial insemination. Of the many advantages which can be cited in favor of artificial insemination, the more important are as follows:

1. The greatest advantage is that of widely extending the use of a good proven sire and making his services available to many who otherwise could not afford it. With the use of newly developed techniques of artificial insemination it is possible to mate a bull to several thousand cows annually By natural service a hundred would be the outside number.
2. For small herds the cost of bull service is greatly reduced. The cost of keeping a bull is about the same as that of a milking cow.
3. Good proven bulls may often be used for artificial service after they become incapacitated for natural service.
4. Artificial insemination is one of the most effective means of controlling venereal diseases such as trichomoniasis, since the bull may be kept free from contamination. It should be emphasized that infected bulls under artificial insemination service extend any infection more than under natural service, by virtue of the much larger number of cows served.
5. Matings may be made between animals at great distances. Semen shipped from a Jersey bull in Bucks County, Pennsylvania to Australia resulted in at least one calf.
6. Artificial insemination guarantees the elimination of injury to small cows and young heifers that often occurs from natural service to large bulls.
7. Young bulls can be proven more rapidly and with less risk to any one individual by mating 30 or 40 cows scattered among different herds.

Disadvantages of artificial insemination. It should be recognized that there are some disadvantages connected with artificial insemination even if the work is done as is essential, by a skilled technician.

1. The owner must detect the cows that are in heat and report to the insemination service in time for insemination. Failure to do this is the most common cause of delayed breeding.
2. Because of the delay between ordering the semen and the actual insemination, cows are sometimes inseminated too late for conception.
3. Under most setups it is not always possible to obtain the semen from the bull that is the most desirable.

THE TECHNIQUE OF ARTIFICIAL INSEMINATION

With the extension of artificial insemination great strides have been made in the development of techniques in the collection of semen, its dilution, storage, and transportation and in the technical aspects of the introduction of the semen into the female tract. Much more research is still needed to improve still more the effectiveness of the methods used. Underlying all of this work is the understanding of the anatomy and physiology of the reproductive organs and their accessories in both the male and the female.

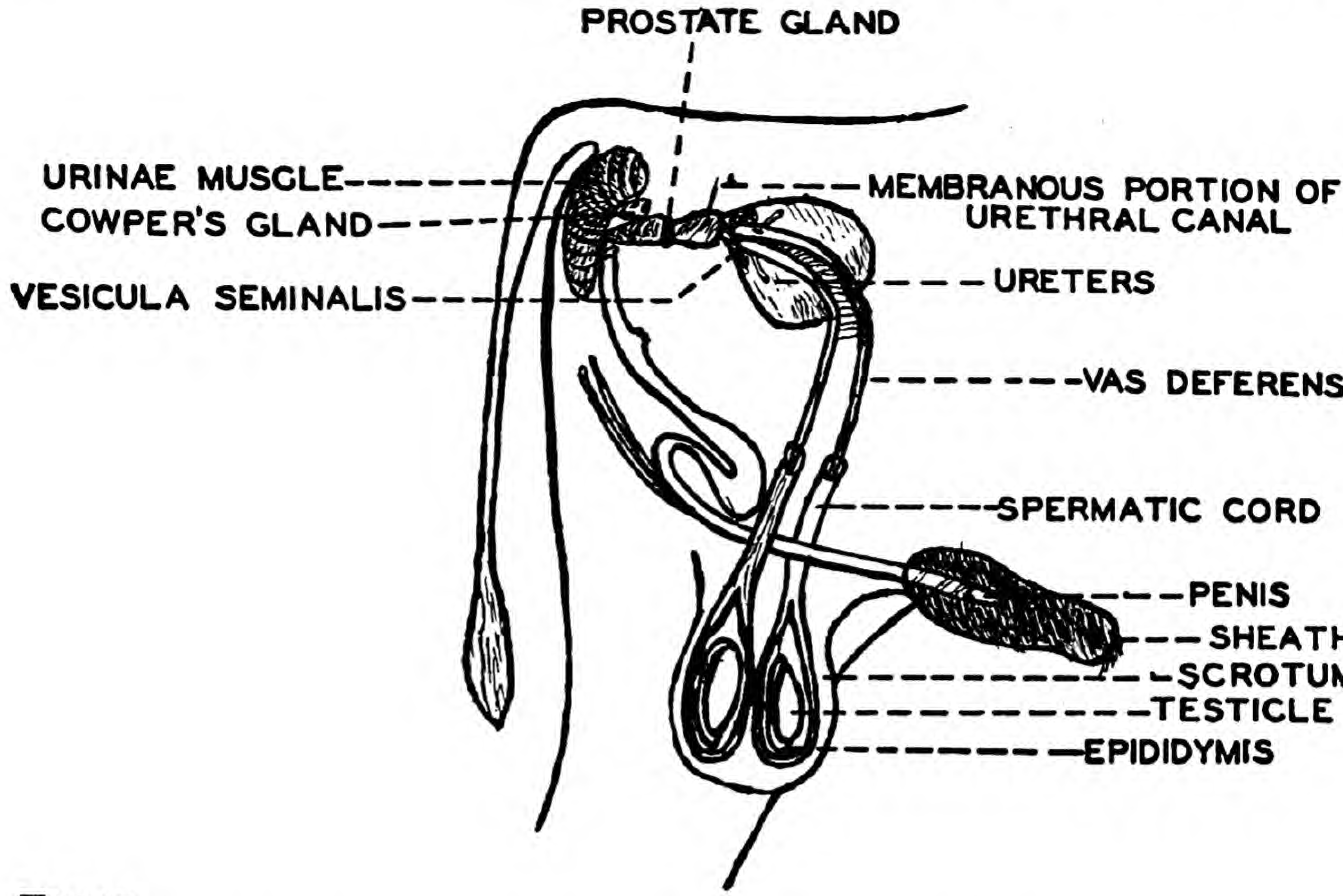


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Fig. 60. This is a diagram of the reproductive tract of the bull.

The male reproductive organs. The male reproductive organs consist of the testes, epididymis, vas deferens, prostate gland, Cowper's glands, urethra, and penis.

The *testes* or testicles of the bull are oval but elongated in outline with the long axis on the vertical. They vary greatly in size from a mean in the mature bull of about 11 cm. in length and 7 cm. in width. Their average weight is about 300 grams. The main features of their structure is the seminiferous tubules and the interstitial cells. The bulk of the testes in made up of convoluted tubules, in the walls of which are formed the sperm. The interstitial cells are endocrine (cells of internal secretion) and produce the male sex hormone which is required to maintain the normal function of the accessory glands as well as the secondary male characteristics.

The *epididymis* consists of a head which lies mainly on the dorsal side and curves over on the anterior part of the testicle, a body which is long and narrow extending from the head backwards and down the posterior side of the testes, and a tail which is attached to the lower side of the testes. It is connected with the tubules by ducts through which the sperm pass. The epididymis serves as a place for storage of the sperm and in which they undergo a ripening process.

The *vas deferens* or sperm duct is a long narrow tube connecting with the epididymis at the lower edge of the testes, then pursuing a flexuous course along the posterior side of the testes. From here the tube proceeds straight up through the inguinal canal to join the urethra posterior to the bladder. Just before joining the urethra and and on either side they enlarge for 10

to 12 cm. to widths of 1.2 to 1.5 cm. into what is known as ampullae, the storehouses for the sperm. Massage of the ampullae will often cause an ejaculation. The ducts then pass under the body of the prostate gland and enter the urethra just below the seminal vesicles.

The *seminal vesicles*, lying one on either side of the ampullae, are 6 to 10 cm. long and 3 cm. thick. Each one is a thick walled tube bent on itself in a tortuous manner. They empty into the ampullae alongside the point at which they empty into the urethra. The seminal vesicles secrete a thick viscous fluid which is alkaline and contains globulin. This secretion is added to the contents of the ampullae and serves as a carrier for the sperm.

The *prostate* is a small accessory gland located at the neck of the bladder, surrounding the urethra. It measures 3½ to 4 cm. by 1 to 1.5 cm. It has a branched lobular structure. The secretions, which are alkaline, run directly into the urethra through a series of ducts. The function of the secretion is not known but it is thought that it aids in cleaning out the urethra.

The *Cowper's glands* or bulbo-urethral glands are two small glands one on each side of the urethra. Each has a single duct emptying directly into the urethra to mix with the secretions of the prostate and the products of the ampullae when expelled into the urethra.

The *penis* serves to empty the bladder and as an ejaculatory organ. The outstanding feature is an S-shaped flexus just posterior to the scrotum in which about one foot of penis is folded back. On erection the flexure is effaced.

The female organs of reproduction. The female reproduction organs begin, at their inner terminus with the ovaries, which are followed by the Fallopian tubes or oviducts, the uterus cervex, vagina, and finally, the external vulva.

The *ovaries* consist of one oval body on each side measuring 3.5 to 4.5 cm. in length, 2.5 cm. in width, and 1.5 to 2 cm. in thickness. They are located near the middle of the pelvic inlet on either side—in the nonpregnant female. They are rather easily palpated through the rectum. In advanced pregnancy they may be drawn considerably forward.

The ovaries produce the eggs or ova and also two important hormones. Estrogen or the female sex hormone is produced by the follicles as they develop. The secretion of this hormone is at its height when the follicle is near its rupture state and the egg is ripe. It is this hormone that produces the heat or estrus symptoms.

Upon rupture of the follicle, it is replaced by a yellow body known as the corpus luteum. This body produces another hormone known as progesterone or the pregnancy hormone. If pregnancy ensues, this body becomes persistent during the gestation period when its secretion is essential to maintain the gravid state. Expulsion of the corpus luteum produces abortion. If pregnancy does not ensue following ovulation, the corpus luteum regresses and new follicles occur to repeat the process, normally requiring 21 days for a complete cycle.

The secretion of the two ovarian hormones is regulated by pituitary hormones known as gonadotropins. There are two of these, one known as

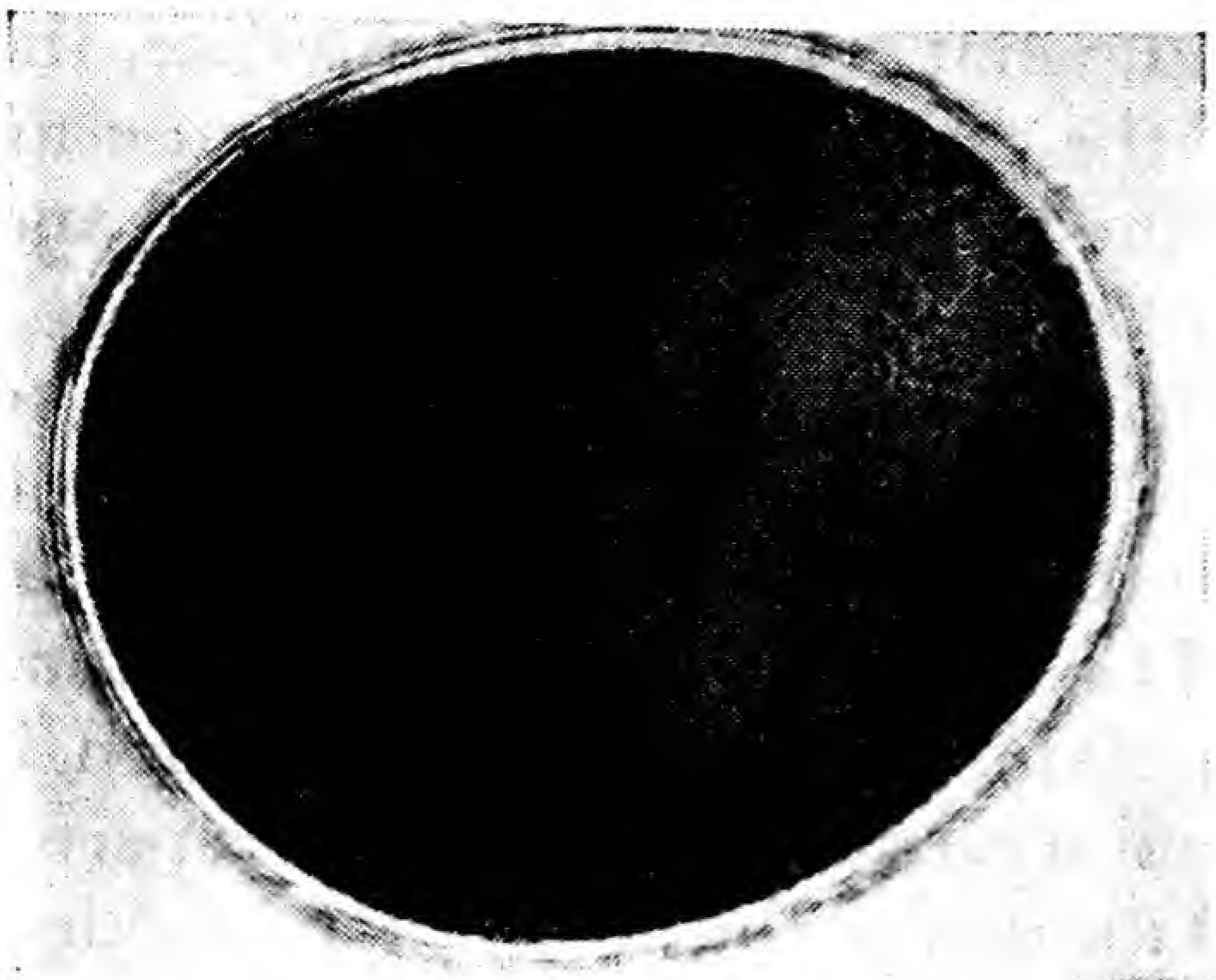

Fig. 61. This is a fully developed egg six days after fertilization. It is 120 micra (.12mm.) in diameter.

FSH—follicle stimulating hormone —which causes the follicle to grow and secrete estrogen. The other known as the LH or lutenizing hormone, causes the corpus luteum to grow. It is generally held that estrogen depresses the secretion of FSH and progesterone that of LH. This interaction is alleged to be responsible for the cyclic rhythm.

The ovaries are subject to malfunction, some of which can be detected by examination of them through the rectum by skilled operators. An expert is able to tell from such an examination whether follicles, corpora lutea, or cysts are present. The stage of the cycle can also be reasonably estimated. Cysts can be ruptured and persistent corpora lutea can be expelled; however, these operations should not be attempted by anyone not skilled in the art.

Fallopian tubes are two in number, one from each ovary to the tip of the horn of the uterus on the respective sides. They are long, slender, somewhat flexuous tubes for the conveyance of the eggs from the ovary to the uterus. The egg escapes from the ripened follicle at its rupture into the tube. It is in the tube that the egg is fertilized by sperm that travel up the tube assisted by the cilia found in its walls.

The occlusion of the Fallopian tube as the result of infections is a cause for sterility. Whether other possible dysfunctions of these organs contribute to sterility is not known.

The *uterus* is a hollow organ consisting of a body and two horns. The body is only 3 to 5 cm. in length and each horn from 35 to 40 cm. long in the nongravid condition. The horns taper and curve to form a spiral coil laterally. Implantation occurs in the horns and under this condition they enlarge enormously and are drawn forward into the abdominal cavity. The uterus is suspended from the dorsal wall of the cavity by strong ligaments known as the dorsal ligaments.

The walls of the uterus are thick and muscular. The inside of these walls are provided with uterine cotyledons, oval prominences numbering a hundred or more. These cotyledons form the basis for connection with the fetal membranes.

The uterus is subject to malfunction which prevents implantation of the embryo. Some of these are suspected to be of endocrine origin while others are due to a pathological condition.

The *cervix* is about 10 to 12 cm. in length and 3 cm. in thickness. Its wall is very firm and the lumen, known as the cervical canal, is spiral and invested with several folds. The cervical canal is tightly closed and because of the folds it is difficult to penetrate. Goblet cells in the cervix walls

secrete a mucus which is especially thick during pregnancy, when it forms as a mucous seal. During estrus the cervical canal relaxes somewhat. The cervix protrudes into the anterior part of the vagina where it may be plainly seen through a speculum.

The *vagina* in the nonpregnant cow is from 25 to 35 cm. in length. It is invested with numerous folds and has great capacity for enlargement. The walls of the vagina secrete mucus and maintains in normal conditions a constant bacterial flora. Just what part abnormalities in the secretions of the vaginal walls may play in infertility is largely a matter of conjecture at the present.

Characteristics of semen. Normal semen is an opaque light-creamy to creamy fluid that is somewhat viscous. It consists of fluid and cellular parts. The fluid serves as a carrier and nutrient medium for the sperm. The fluid is chiefly secretion products of the seminal vesicles, prostate and Cowper's glands. The cellular part consists of the spermatozoa products of the tubules of the testes. Normal sperm are somewhat tadpole-like in structure, consisting of a headpiece, middlepiece, and tail. The total length is about 10 micra. The concentration of sperm varies greatly from very few in a condition known as aspermia to several thousand million per milliliter.[1] The volume per ejaculate also varies widely from 2 to 10 ml. The *p*H of bull semen also varies [2] with an average or normal of about 6.5. Bull semen has a high buffering value [3] at two points, one on the acid side between *p*H 4.0 to 5.5 and the other on the alkaline side at *p*H 9.0 to 10.00.

Collecting semen. The objective in collection of semen is to get a complete ejaculation free from contamination. The artificial vagina and other appurtenances are now standard equipment in veterinary and livestock supply houses. The important points for consideration is the proper handling of this equipment and the bull. First in importance is the point of having the artificial vagina and all parts with which semen comes in contact absolutely clean and sterile. This is essential to prevent contamination of the semen and to avoid taking the chance of infecting bulls by contamination of the artificial vagina from a previous service. All long hair from the sheath should be clipped.

The next important phase is that of having the artificial vagina warm and lubricated. It should be warmed with water introduced in the water jacket so that the inside temperature is 105° to 110° F. This inside temperature is usually attained by filling the jacket with water at 132° F. The inside of the vagina should be coated with petroleum jelly or vaseline, preferably applied with a long glass rod. About half of the warm water in the jacket should be removed just before service.

One of the really big problems in artificial insemination centers is that of so handling the bulls to get prompt and full ejaculations. In all cases it is important to avoid any unpleasant incidents that the bull may associate with the act. Many bulls have become unusable for artificial in-

[1] Edwards, G. Biology of Human Affairs. 12:121. 1947.
[2] Swanson, E. W. and Herman, H. A. Jour. Dairy Sci. 24:321. 1941.
[3] Sedgwick, E. S. and Asdell, S. A. Cornell Vet. 30:499. 1940.

semination work because of accidents in the first attempted service. Bulls vary greatly in the way that they respond to different people and environmental conditions. Careful study of the factors that favor or deter from the best performance of each bull in a stud and adjusting the techniques accordingly is essential for the best results.

The New Jersey Experiment Station [1] reports that when two ejaculates are taken in succession, the second exceeds the first by about 75 per cent in volume, with about the same sperm concentration per milliliter and slightly greater longevity of the sperm. They report that when a bull has not been used for a week or more the first ejaculate was frequently "small in volume and watery in nature." In such cases a second sample should always be taken.

Semen has been taken by other methods than by the use of the artificial vagina. One involves the removal of the semen from the vagina of a cow served naturally. This method is not satisfactory, largely because of the contamination of the semen from the vaginal secretions. Another is the massage of the ampullae via the rectum, by which their contents may be expressed. Two operators are needed—one to do the massaging and the other to collect the semen. The volume is usually small and often contaminated with urine. This method is restricted, therefore, to bulls that refuse or are unable for physical reasons to use the artificial vagina.

Care of collected semen. *Cooling.* Sudden cooling is harmful to sperm. Therefore, in cold weather, the collecting tube of the artificial vagina should be protected against exposure. First, immediately after the ejaculation the tube should be protected by inclosing it in one hand while the other hand holds the vagina perpendicularly for drainage of the semen. Upon completion of this act, the tube should be stoppered and placed in a thermos bottle at 82° to 85° F. until taken into a warm room for further preparation. If it is to be used within two hours, it may be kept at this temperature. If its use is to be delayed, it must be cooled gradually to about 41° F. Proper cooling to this temperature is obtained by immersing the tube containing the semen in a pint of water at 80° F. and placing in a mechanical refrigerator. Another method is to place the tube containing the semen in a closed pint jar containing an inch of cotton, before putting into a refrigerator at 41° F.

Dilution of semen. A number of diluents have been developed for diluting semen, and make it possible to increase the number of cows that can be bred from one ejaculate and that facilitates storage of the semen. In experiments [2] with appropriate diluters good results have been obtained with dilutions up to 100 times. The more customary dilutions are 1 to 16 times or less.

There have been developed several satisfactory diluters, of which the following are most commonly used:

1. The phosphate-egg yolk diluent [3] is prepared by adding to 100 ml.

[1] Perry, E. G. and Bartlett, J. W. N. G. Agr. Expt. Sta. Extension Bul. 235. 1943.
[2] Salisbury, G. W. Jour. Dairy Sci. 29:695. 1946.
[3] Phillips, P. H. and Pardy, H. A. Jour. Dairy Sci. 23:399. 1940.

boiled distilled water, 2.0 grams mono-potassium phosphate (KH_2PO_4), 2.0 grams disodiumphosphate ($Na_2HPO_4 \cdot 12\ H_2O$), and an equal volume to the above mixture of egg yolk.

The yolk should be from fresh eggs. After the egg is freed from albumin, it is held over a sterile dish and the membrane cut to permit the yolk material to flow out. Extreme care should be taken to prevent contamination. The yolk should be added to the phosphate mixture at about 100° F.

Another diluent, developed at Cornell University,[1] is known as the yolk-citrate diluent. It is equal in preservative value to the phosphate-egg yolk diluent and has the advantage that the fat particles in the yolk are dispersed to make possible microscopic examination of the sperm in the diluent. A M/15 solution of sodium citrate is used with equal volumes of egg yolk. The M/15 sodium citrate is made up by mixing 4.7 grams of $2Na_3C_6H_8O_7 \cdot 11H_2O$ to 100 ml. with boiling distilled water. This mixture is cooled to room temperature before the egg yolk is added.

The degree of dilution will depend upon the quality of the semen and the amount needed. While satisfactory results have been obtained by great dilutions, it is still advisable to keep dilutions to a minimum. Diluting one volume of semen to 16 with standard diluents is now done routinely by many workers when the original semen is of good quality. Others still prefer not to dilute beyond 1 to 6.

The diluents should be ready before the semen is taken, and should be adjusted to the right temperature—that of the semen sample—when the mixing is done. Immediately after dilution, the samples should be cooled under the conditions previously described. The cool storage is necessary to conserve the energy of the sperm and to keep bacterial development low.

Tests for semen quality. There are a number of tests that can be applied to semen samples that will assist in evaluating its probable fertilizing ability; however, there is as yet no known method that is infallible. By appropriate tests some samples can be eliminated that are of no value, but samples that pass known practical tests may still have poor fertilizing value. Following are some of the more important criteria:

1. *Physical appearance.* If the specimen appears watery, yellow, or pink, the chances are that it will not be good enough to use.

2. *Volume of ejaculate.* This will vary with different bulls, but if the volume is much smaller than normal for a particular bull it is likely to be of poor quality. A second ejaculate should then be taken.

3. *Abnormal sperm.* When examined microscopically, the sperm should show normal proportions of head, middlepiece, and tail. The tail should extend straight from the middlepiece. When the tails are absent or crooked or the heads misshaped in any significant number, it is of low quality and should be discarded or used undiluted.

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[1] Salisbury, G. W., Fuller, H. K., and Willett, E. L. Jour. Dairy Sci. 24:905. 1940.

4. *Motility.* When a drop of undiluted semen is observed microscopically under a cover slip at about 100° F., there should be a vigorous swirling motion. Good fresh semen should have 85 to 95 per cent of the sperm motile. Semen with a motility of 50 to 60 per cent may be used but should not be diluted. The most significant aspect about motility is its persistence; good semen retains its rate of motility after storage. In addition, the length of time a sample of semen will remain motile under incubation conditions gives promise of being a good indicator of its quality.[1]

5. *Methylene blue reduction.* Adding a standard methylene blue solution to semen and noting the time required for decolorization, was at one time considered a good test for semen quality. The good specimens were believed to decolorize faster because of their greater metabolic rate. More recent work has shown this test to be of little value.

6. *Respiration rate.* A rather simple apparatus has been devised [2] to measure the respiration rate of semen. Its value in predicting semen quality has not been established.

7. p*H of semen.* The *p*H of the original sample of semen likewise has not been shown to be of any practical value in establishing its quality.

Shipping semen. It is important that semen stored under refrigerator conditions not be warmed up in shipment. To prevent this a number of devices have been constructed. The simplest is that of putting the semen samples in a well-insulated cardboard box or large mailing tube in which is placed sufficient quantities of ice, held in ordinary rubber balloons. The semen tubes should be protected from direct contact with the ice by suitable wrapping with paper.

Insemination. For introduction of the semen a glass syringe is connected by means of rubber tubing to a glass tube about 16 inches long, with a 1 mm. inside and at least 6 mm. outside diameter. The end of the glass tube is firepolished. This tube is sterilized and a fresh one used for each insemination.

There are three methods of introducing the semen. The simplest and least satisfactory is that of depositing it in the vagina somewhere near the *os uteri*. The second method requires a speculum that permits view of the cervix while the inseminating tube is inserted into the os for the implanting of the semen. The third method—one that is gaining in favor—is commonly known as the rectal method because one hand of the operator is placed in the rectum where the cervix is grasped while the other hand guides the inseminating tube through the vagina into the os. By manipulation of the cervix through the rectum the tube in most cases may be easily passed through the cervical canal into the uterus. During estrus the cervix is usually relaxed. The semen may be partly deposited in the uterus and partly in the cervix as the inseminating tube is withdrawn. Some object

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[1] Personal Communication from Dr. T. M. Ludwick. Univ. of Kentucky.

[2] Comstock, R. E. and Green, W. W. Amer. Soc. Anim. Prod. Proc. 32nd. Ann. Mtg. 213. 1939.

to any deposition in the uterus, claiming danger from possible bacterial infection. In Denmark, on the other hand, insemination into the uterus proper is a routine operation.

The amount of diluted semen used varies somewhat. Some use as little as ½ ml. generally, however, 1 to 1½ ml. is used.

CO-OPERATIVE ARTIFICIAL INSEMINATION SOCIETIES

Artificial insemination societies vary from small local units having one inseminator and breeding as few as 1,000 cows to statewide organizations employing scores of inseminators and breeding more than 100,000 cows annually. The trend is toward the organization of the larger units because of their several advantages. Because of the greater number of cows that can be served by one bull in the larger units, the cow service cost is reduced. For that same reason better and higher priced bulls may be obtained. The larger unit has a lower cost of maintenance per bull and can have better facilities for handling them. The larger organization can also have better laboratory facilities and technicians. These advantages offset the disadvantage of shipping the semen to the outlying centers.

The success of an artificial insemination society depends upon many factors. The first is that the conception rate must be equal or nearly equal to that obtained by natural service. Oft repeated services for conception is listed as a complaint of the first order which has been responsible for many departures from the organization—irrespective of who was at fault. High conception rates are dependent on fertile bulls and good technique in the handling of the semen and in the actual insemination. Therefore, one of the first requisites is that of obtaining the best possible technicians and managers. Herd owners are also often at fault in not reporting the cows in estrus until too late.

The most important long-time factor in the success of the society is that of having enough cows within a sufficiently short geographical radius as not to make the cost prohibitive. A minimum of 1,000 cows within a radius of 15 to 20 miles has been set as the lower basis for a unit to succeed. Good inseminators with uniform distribution of breeding throughout the year can handle 3,000 or even more cows within a radius of 20 miles.

Adequate finance is another important factor the lack of which has caused many associations to fail. The service fee should be high enough to permit the building up of a surplus and still not so high as to discourage new members. The larger the volume of business the lower will be the cost.

It is imperative that the bulls used be free of any communicable disease. It is obvious that, because of the large number of cows served by one bull, infection, if it occurs, can be spread widely.

Lastly, the problem of helping members with a breeding program and setting up a system where young bulls are developed and proven is a phase that must be given more attention than has heretofore been the case.

RESULTS OF ARTIFICIAL BREEDING

Artificial insemination is still too new to have extensive data on accomplishments. The first published analysis [1] of the oldest association compared 120 daughters of artificially sired daughters with their dams with the following results for 305-day lactation periods:

	Pounds of Milk	Pounds of Fat
120 "artificial" daughters	8,557	329.9
120 dams	7,823	287.7
Increase	734	42.2

This is an increase of 14 per cent in fat and 9.3 per cent in milk.

In the March, 1948 analysis of the performance of 13 proved Holstein sires by the New York Artificial Breeder's Cooperative, Inc., daughters of the bulls were compared with their dams at different levels of production. The results are presented in the following table:

Dams' Production	Comparison of:	Milk	Fat
Up to 299 pounds fat	25 daughters	9,635	341
	25 dams	7,959	265
	Difference⟶	+ 1,676	+ 76
300–349 pounds fat	49 daughters	10,356	365
	49 dams	9,679	332
	Difference⟶	+ 677	+ 33
350–399 pounds fat	71 daughters	11,688	419
	71 dams	10,953	375
	Difference⟶	+ 735	+ 44
400–449 pounds fat	96 daughters	12,013	423
	96 daughters	12,092	425
	Difference⟶	− 79	− 2.0
450 pounds fat and over	123 daughters	13,236	480
	123 dams	14,061	511
	Difference⟶	− 825	− 31

It will be noted that these bulls sired daughters with greater production than their dams when the dams did not average more than 375 pounds fat. When the dams averaged above 450 pounds of fat, the daughters of these bulls averaged less than their dams.

Comparative conception rates. Numerous studies have been made on the comparative conception rates for artificial insemination and natural service. As would be expected considerable variation is found in these reports, the main influences being the technical skill employed and the state of fertility of the bulls used. Co-operation on part of the herd owners in promptly reporting the cows to be bred in also a factor. The importance

[1] Perry, E. J. and Bartlett, J. W. N. J. Agr. Expt. Sta. Circ. 489. 1944.

of the time of breeding with relation to the estrus stage is brought out by studies at the Nebraska Station.[1] Inseminating cows in various stages they report the following:

Stage Bred	Conception Rate (*Per Cent*)	Number of Cows Bred
Start of estrus	44.0	25
Middle of estrus	82.5	40
Middle of estrus and rebred in 24 hrs.	84.0	25
End of estrus	75.0	40
6 hours after end of estrus	62.5	194
12 hours after end of estrus	32.0	40
18 hours after end of estrus	28.0	25
24 hours after end of estrus	12.0	25
36 hours after end of estrus	8.0	25
48 hours after end of estrus	0.0	25

From all of the reports it can be concluded that the conception rate from artificial service can be as high as from natural service.

[1] Trimburger, G. W. and Davis, H. P. Agr. Expt. Sta. Research Bul. 129. 1943.

Chapter 27

THE PUREBRED BUSINESS

A PUREBRED ANIMAL IS GENERALLY UNDERSTOOD AS ONE THAT TRACES back through all of its lines to the foundation stock of the breed it represents. To this must be added those animals that have been graded up by successive use of purebred bulls to become eligible for registration in the herd books of the breed associations that have provisions for this system. The Shorthorn and Danish Reds have grading up provisions patterned after that used in Great Britain for dairy breeds. When purebreds are registered with the breed association, they are known as "registered" stock. Purebreds are sometimes incorrectly referred to as "thoroughbreds." Another term used, but not considered good form, is "full bloods."

While the number of purebreds comprises but a relatively small percentage of all dairy cattle, the purebred business has been one of the most influential factors in the development of the dairy industry. The breeders of purebred cattle have not only furnished purebred bulls that have graded up the dairy herds, but through individual effort and their breed associations, they have been responsible for the initiation and prosecution of many of the most far-reaching dairy development programs. The general aspiration of the breeder of purebred cattle to breed superior stock has resulted in immeasureable improvement of the purebreds. This, in turn, has been reflected in improvement of grades where purebred bulls have been used. The hope of future improvement of dairy cattle lies mainly with the breeders of purebred cattle. If they make rapid strides in improvement, the general level of dairy cattle will be raised proportionately.

Extent of the purebred business. Accurate information as to the exact number of purebred dairy cattle in this country is not available. A fair estimate is that between 5 and 6 per cent of all dairy cattle are purebred. The actual number as well as the percentage of all dairy cattle that are purebred is on the increase. From 1920 to 1930 it was estimated that the percentage of purebreds rose from 3.1 to approximately 5. During the 1930's many purebred cattle were not registered because of the effects of the depression. Interest in purebred breeding was at an all-time high, with the largest registration ever recorded in 1947.

The main purpose of the purebred is not to furnish milk for the market, but to supply bulls for use in the dairy herds of the country. At present, there are only enough purebreds to furnish one-half of the bulls used in the United States. How many purebreds will be needed to furnish bulls for the future is open to conjecture. The number of bulls needed can be reduced by using bulls for a longer period of service and through co-operative ownership. How soon changes in this direction will take place, only time will tell.

Purebred vs. grade. Recent comparison of grades and purebreds that were tested in Dairy Herd Improvement Associations showed that the purebreds have produced about 25 pounds more butterfat annually than the grades. It is claimed by some that this is not a significant difference, and as a result purebreds have been subject to criticism on the grounds that they are not superior to grades. The criticism is unwarranted, first, in that the difference is significant, and second, in that the comparisons are not justified. Dairy Herd Improvement Association records include the better grades; this is evidenced by the fact that the average butterfat production for all cows in testing associations is 349 pounds of fat, while the average for all cows milked in the United States is reported as being 190 lbs. of fat.[1] Since many of the purebreds tested in Dairy Herd Improvement Associations are from herds with mixed grades and purebreds (beginners in breeding purebreds), the purebreds would naturally not be as good as those from older purebred herds. Dairy Herd Improvement Association figures, therefore, compare the best of the grades with the poorer of the purebreds. This is supported by the fact that in Dairy Herd Improvement Associations, where good purebred herds are entered, the purebred usually leads with the highest production records. While the Advanced Registry records are not directly comparable with the Dairy Herd Improvement Association records because of the better conditions under which the Advanced Registry records are made, such records are given for what they are worth, and are as follows: [2]

Guernseys	500.8 lbs. of fat
Holsteins	572.1 lbs. of fat
Jerseys	457.5 lbs. of fat
Brown Swiss	546.0 lbs. of fat
Ayrshires	364.5 lbs. of fat

These are, as is noted, considerably higher than the average of 349 pounds of fat for all cows tested in the Dairy Herd Improvement Associations. The important point in discussing the relative merits of purebreds and grades is not so much the differences in averages, but that there are purebred herds which are much superior in their producing ability to any grade herds. As the future grades must come from the purebreds of today, it is encouraging to note that there are a large number of purebred herds of superior producing ability. It is not to be argued that all purebreds are superior. If the same amount of culling were practiced in the purebred herds as has been practiced in the grade herds, the purebred averages would be considerably higher than they now are. One of the very important steps that the purebred breeders can take, and must take for their own security, is that of more rigid culling of the lower producing groups.

Desirability of breeding purebred cattle. For one who is desirous of making a permanent contribution to agriculture the breeding of purebred cattle is commended, provided he has the proper qualifications. By de-

[1] Report of Chief Bur. Dy. Ind., Sep. 1, 1947.
[2] Figures furnished by the Breed Associations.

veloping superior cattle a contribution is made to agriculture that is more far-reaching than is usually granted.

Attention has already been directed to the work of the great English breeders in developing superior strains of livestock, the benefits of which have extended to this time. Bates alone started the Milking Shorthorn; descendants numbering into the hundreds of thousands owe their dairy heritage to the work of this one man. The work of Dauncey with Jerseys is of a similar magnitude, and that of many others can be cited.

Possibilities still exist of developing strains that have the same relative superiority Bates' Shorthorns did over the common Shorthorn of his day, and that may have the same far-reaching effect upon the future of any breed. In addition to the challenge of producing something that will contribute to improved cattle for all time, the breeding of purebred cattle offers many other desirable features. For those who like art there is the challenge to the production of beautiful animals and the showing of them.

The purebred breeders have formed a fraternity from which much can be gained. The roster of purebred breeders of dairy cattle contains many of the leading names of successful leaders in America, including several presidents of the United States.

Qualifications for the breeder of purebred cattle. Not only must the breeder of purebred cattle be able to care for a dairy in the same way that an ordinary dairyman must, but he must possess a number of additional qualifications for success. First of all, he must be honest and have a reputation for honesty. The very nature of the purebred business depends upon the integrity of those who breed cattle. The breeder must report the parentage of all animals bred by him, and unless he has a reputation for honesty and integrity, little faith will be had in the cattle that he breeds. To be successful in breeding purebred cattle, a man must be somewhat of an idealist, in that he must be able to vision a goal toward which he aspires to develop his cattle. Then he must know the fundamentals of breeding so that he will be able to map out a comprehensive program in his attempt to reach the ideal goal. Lastly, if he wishes to make a financial success of his enterprise, he must possess business ability. The successful execution of the purebred business requires a business ability quite different from that required in producing and marketing milk. Some of the most successful producers of milk have failed in the breeding of purebred cattle. With all of these qualifications as requisites for success in the breeding of dairy cattle, it is no wonder that this business has challenged so many outstanding men in contemporary American life.

Registration. While not all purebred cattle are necessarily registered, registration furnishes the only proof of animals being purebred. Each breed association has developed an excellent system of registration. One of the chief objects of a breed association is that of registering the cattle and the accurate keeping of records. Each breed association requires that to register an animal, an application to the association must first be made on the proper forms; this application carries the necessary affidavits as to the correct parentage of the animal.

Testing. While all systems of testing are open to the breeders of purebred cattle, there are two systems that are restricted for the use of breeders of purebred cattle. These are the Official Test and the Herd Test systems. Each of these systems has been discussed under each of the breeds. The keeping of production records was first limited to purebreds. Breeders of cattle should always have the keenest interest in securing production records. For the owner of grades, production records are of use in determining the economy of production. For the purebred breeder, in addition to this value, records have an additional value in the proper evaluation of the genetic makeup. If it is argued that all grades should be tested, it is infinitely more important that all purebreds should be tested. There is nothing in the business of breeding cattle that is so essential as that of securing production records on every individual.

Public sale. Since there is no market where the values of purebreds are determined, as there is for butter, beef cattle, and other standard commodities, it is necessary for purebred breeders to find some way of ascertaining the values of purebreds. This need has found expression in the public sale, of which there are two kinds: the consignment sale, and the individual sale. The consignment sale is a sale where a number of breeders each consign one or more animals. Aside from the ulterior motives that the promoter of such a sale may have, its prime purpose is to establish values for purebreds. The individual sale may be held for several reasons. It may be a "closing out" sale when the breeder decides to quit the business, or it may, in the breeder's judgment, be the easiest way of disposing of surplus stock. Whatever the reason, the individual sale, like the consignment sale, contributes to the establishment of values for the purebreds.

There are many advantages and disadvantages in the public sale. In addition to being an instrument for establishing values, it may be a convenient instrument for the disposal of surplus stock. Since the animals offered at public sale must be sold to the highest bidder, the consignor is taking considerable chance in getting full value for his consignment. Unfavorable weather or other conditions may limit the number of buyers and result in greatly lowered prices. Frequently, however, the public sale is responsible for the highest prices paid for cattle. If two or more people become interested in the same animal, the sales management, who are experts in sales psychology, will see that a top price is obtained. Auctioneers are rated upon their ability to arouse enthusiasm among the buyers. The beginner who proposes to buy cattle at an auction sale would do well to solicit the aid of someone who is more experienced. The unsophisticated person is very likely to be swept along on the wave of enthusiasm created by the sales management; this accounts for some unreasonable sales prices. While most auction sales are conducted honestly, there is the danger of some "by-bidding." This practice is forbidden, and no honest organization will tolerate it.

Advertising. It is up to the breeder to find his own market, since there is no well-established market where values are fixed and to which a breeder may consign his surplus animals. In order to find a satisfactory market, it

is necessary that the breeder be known not only for his honesty but also for the quality of his stock. It is, therefore, to his advantage to get himself and facts about his cattle before the public at every possible opportunity. Paid advertisements in publications reaching potential buyers are a common and effective means of informing the public about animals offered for sale. There are, however, many other ways by which a breeder can keep himself and his breed before the public. Some of the more important ones are:

1. Maintenance of a neat farmstead with a well-chosen farm name placed in a conspicuous place.
2. Acting as host to farm meetings. This not only brings the breeder in contact with the attendants at the meeting, but gets him additional publicity in the publicizing of the meeting.
3. Showing meritorious animals at the proper shows. This is a very effective means.
4. Furnishing news items. Having news items about his herd in the local papers as well as in his breed publications is most effective.
5. Public service. A breeder should never turn down an opportunity to serve as an officer in his breed association or other chances at public service.
6. Attending breed meetings. He should make special effort to attend all meetings, sales, and picnics sponsored by his breed.

Naming the farm and the cattle. As has been pointed out, a breeder should always strive to keep his name before the public. One effective way of accomplishing this end is to adopt a farm name as a prefix or suffix in the naming of the cattle. Such a farm name may be registered with his breed association and thus reserved exclusively for the owner of the farm. All animals sold with such a farm name as a prefix become living advertisements of the farm.

Great care should be used in selecting a farm name that is distinctive and easily remembered. The breeder's name may be used if it is distinctive, such as "Hood Farm." Sometimes the initials of the farm or firm forms a distinctive name, such as Femco, derived from F. E. Murphy Company.

In the naming of cattle the system used by the University of Minnesota has proved very satisfactory. The word "Minnehaha" is used as a prefix for all breeds. The second word of the name designates the sire and the third, the female family. Thus the name Minnehaha Matador DeKol would reveal that the animal was bred by the University of Minnesota, is by the bull Valentine Matador, and is out of a family headed by Minnehaha Bess Burke DeKol.

In the naming of bulls, some breeders adopt the system of using the name of the sire with a numerical suffix, as Sir Pietertje Ormsby Mercedes 37th. The advantage of this system is that the name reveals the sire to everyone who is the least familiar with the breed.

Another system of naming that finds favor among many breeders is to reveal the year of birth in the name by using the first letter of the key word in the name for such designation. The first year the letter "A" would be used, then "B," etc.

Business methods. Success in the breeding of purebred cattle is dependent to a large extent upon the use of sound business principles. The first and absolutely essential requisite is the keeping of complete and accurate records filed so as to be easily accessible. Record keeping begins with recording the date of service of the cow and the name of the sire. On the day of the birth of a calf, all the information needed for registration should be carefully recorded, preferably by filling in an application for registry. This may then be filed until the date that the application for registry must be made to the office of the breed association. Upon receipt of the Certificate of Registration, this instrument should be again checked with the animal for possible errors. If it is found to be correct, the Certificate of Registry should be filed either in a suitable envelope or in a loose-leaf book. As all animals should be numbered, the best way of filing is in numerical order. Next a sheet should be entered in the herd book with the name, number, date of birth, and the pedigree of the animal properly entered. As more information about the animal accumulates, entries should be made, so that in the herd book there is available all the essential information about the animal, including the production records.

A second requisite for success in selling purebred animals is to know the essential facts about the animal and be able to state these facts to a prospective purchaser. The successful breeder knows the pedigrees of his stock and, in addition, is generally familiar with the lines of breeding followed by the leading breeders. Knowledge of the breed as a whole is acquired from attendance at meetings and from the breed journals.

A third requisite for sound business and successful salesmanship is prompt and adequate attention to correspondence. A prompt reply to an inquiry, giving full particulars about the animal offered for sale, including the price asked, has a very favorable effect upon the prospective purchaser, while a delay and vague or inadequate description has the opposite effect. A typewritten letter on an attractive letterhead is superior to a letter written in longhand.

A fourth requisite is promptness in furnishing the Registration Certificate and the Certificate of Transfer to the buyer. Failure to furnish these instruments within a reasonable time after the sale causes uneasiness and suspicion on the part of the buyer. In addition to losing such a buyer for a further sale, the unfavorable impression created is likely to spread and do much harm.

Many other minor essentials in conducting a purebred business could be mentioned. Space permits only calling attention to the desirability of follow-up letters. An occasional letter to a previous buyer inquiring as to how the animal or animals sold are doing creates good will and facilitates the making of future sales. If a bull is sold, a letter to the purchaser after the bull has been in service two years, calling attention to the fact that it is time to buy a new bull and that another good one is available on the farm where he purchased the first, is often fruitful of results.

Additional services a breeder should render. The breeding of purebred dairy cattle is a profession. A varying portion of the purchase price of

a purebred animal represents payment for the skill that has gone into the breeding operations which produced that animal. The purchaser, therefore, buys the professional services that the breeder has rendered in the production of that animal. The better breeders are capable of rendering even more in professional services to their clientele, the buyers. They have the opportunity of advising them as to what kind of bulls should be used to give the best results.

The successful breeder, because of his experience and success, is in a good position to offer sound advice to the beginner or less experienced breeder. In making a sale he should feel sure that it is the best for the buyer. If the choice of the buyer is not the right one, for the good of the prospective purchaser the breeder should attempt to persuade a change, even if it is necessary to advise purchase from another herd. The breeder will win in the long run by so doing. Many breeders by rendering this type of unselfish service have built up a clientele that orders year after year, not a specific bull but "the bull that I need now." As a result, many excellent small herds are being developed along the same lines as the larger herds.

The larger breeders, too, can render a splendid service in assisting the owners of the smaller herds who are their "protégés" in selling surplus stock. Such co-operation has much for commendation to all concerned.

Chapter 28

GROWTH AND DEVELOPMENT

THE GROWTH AND DEVELOPMENT OF THE DAIRY ANIMALS IS ONE OF THE important considerations in dairying. As a matter of fact, the livestock industry is fundamentally based upon the phenomena involved in growth. The rate of growth and ultimate size affects production, and factors that influence these are of major importance. It will, therefore, be well to consider the fundamentals of the growth phenomena, the requirements of growth, and the factors influencing rate of growth and ultimate size.

Definition. A satisfactory definition of growth is difficult to give, as the growth phenomena are complex. It may be defined for these purposes as a series of physiological changes through which an individual of any species develops from the fertilized egg to maturity.

Historical. Aristotle (384–322 B.C.) was the first to record observations on the growth of animals in a qualitative way. Theophrastus (372–228 B.C.) recorded similar observations on plants. The idea of systematically measuring growth is a relatively new one. In 1834 Quetelet, an astronomer, reported for the first time on a systematic measurement of children. In 1875 Bowditch, a physiologist at Harvard University, reported on the first comprehensive study of growth in children. In 1891 Minot published the first studies on growth in guinea pigs. To Waters of the Missouri Station goes the credit of starting growth studies in cattle. This work, one of the major research projects, was started in 1906 and has continued at that station. From this rather late beginning, a great interest has been manifested in the study of growth. In 1921 Baldwin gave a bibliography of some 900 papers on the subject.[1]

Growth periods. Growth falls naturally into two major periods, the intrauterine or prenatal period and the postnatal period.[2] Before birth, which marks the division between these two periods, nutrition for the embryo and fetus comes entirely from the dam through the fetal membranes. After birth the nutrient is taken in through the calf's own digestive tract.

The postnatal period lends itself to a further subdivision into two periods—the self-accelerating period and the self-inhibiting period. The self-accelerating period is that period when there is an increase in successive daily gains. This period usually extends to sexual maturity, when the self-inhibiting period begins.

The self-inhibiting period is that period following the self-accelerating period when successive daily gains decrease. This period ends at maturity. In advanced age, there is a shrinkage which is referred to as senility.

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[1] BALDWIN. Mo. Agr. Expt. Sta. Res. Bul. 97. 1927.
[2] Mo. Agr. Expt. Sta. Res. Bul. 96. 1926.

Nature of growth. While the exact cause of growth is not as yet well understood, it is known that the secretions of ductless glands are responsible for the growth stimulation. The glands secreting hormones affecting growth are the thymus, pituitary body, thyroid, and pineal. Just what each one of these glands contributes remains to be discovered.

Growth is taken to include any increment in size. This may be accomplished in two ways: by an increase of the number of cells, or by an increase in the size of the cells. The former is the more important, since all individuals start with the one cell and through cell multiplication develop into creatures having millions of cells. Increase of cell size, however, may be a considerable factor, particularly in the fattening process. Waters [1] found that fat cells might vary from a low as 20 micra [2] in the very thin animal to 200 micra in diameter in the fat animal. The diameters of the muscle cells varied from 20 to 50 micra under the same respective conditions. Robertson [3] found that in rough fed steers the muscle cells averaged 44.8 micra, and in full fed, 62.6 micra. According to Robertson, growth is due to a series of chemical reactions. The velocity of growth during a given period is limited to or governed by one chemical reaction. Brody more recently postulated several phases following one another and overlapping; each one is governed and limited by the law of chemical action. He has adapted formulae to growth phenomena which are based upon the laws governing mono-molecular chemical reaction. Brody and Ragsdale,[4] studying the course of skeletal growth of cattle and making 20 different measurements, found marked differences in the rates of growth of different parts of the anatomy with advance in age. The changes in form with the advancement of age from the calf to the mature animal are illustrated in Figure 62. Here the younger individuals have been enlarged proportionately for all body measurements so that the younger ones equal the older forms in height at the withers. It will be noted that the calf has relatively much longer legs than the mature animal; he is higher over the rump and has a much shorter body. In general, it may be said that the first growth impulses are toward development of the long bones of the legs, followed by a lengthening and deepening of the body, the latter continuing until final maturity. The last major growth change causes a widening of the entire body.

Figure 63 gives the relative per cent of the different measurements of a calf at birth in terms of the mature values.[5] It will be seen that the calf at birth weighs but 6 per cent of the mature weight, while the length of the leg is nearly 70 per cent of the mature value.

Each individual has an inherited limit to size beyond which it will not develop. However, there are parts of the body that continue to grow

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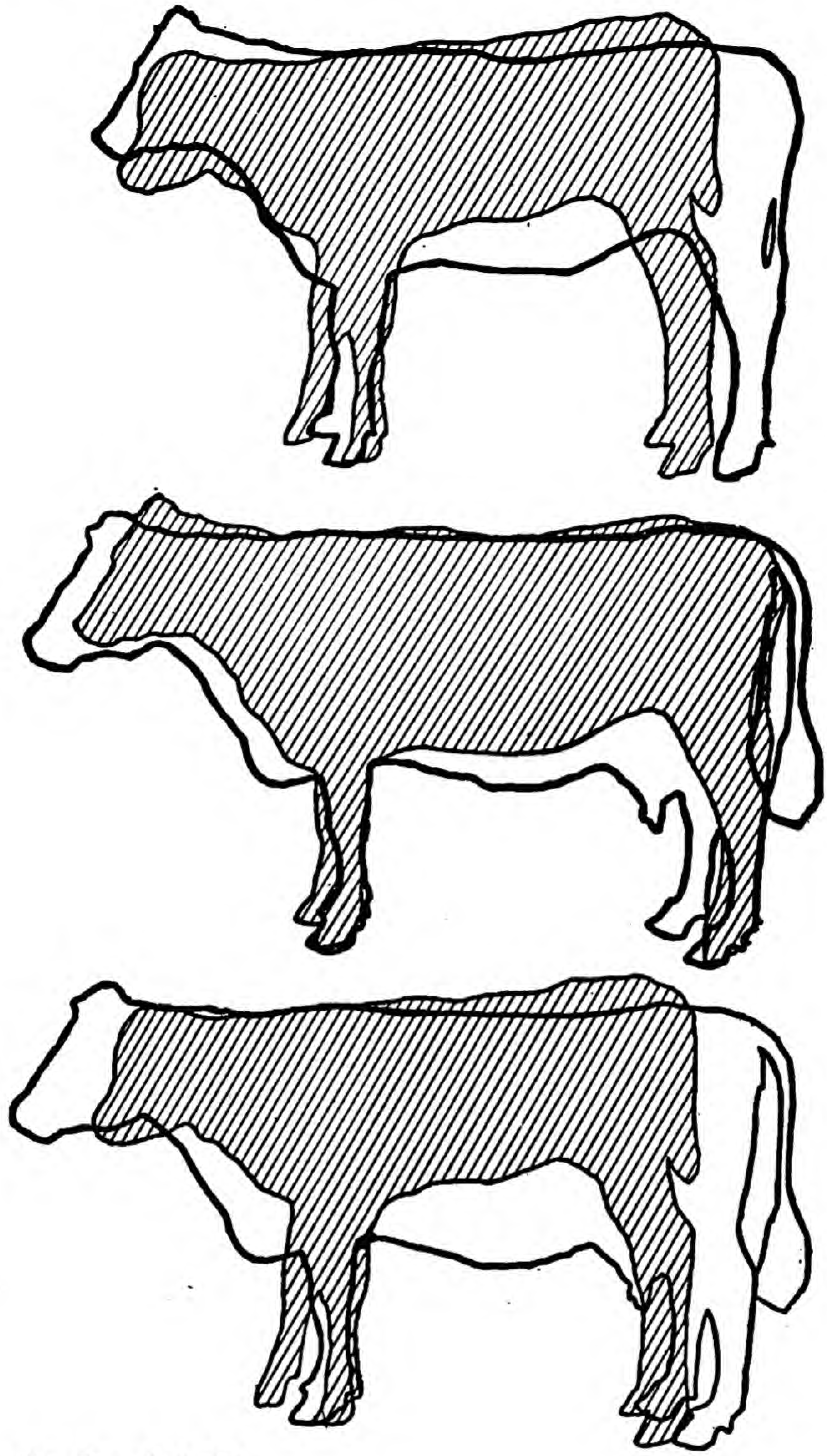
[1] WATERS. Proc. Soc. Prom. Agr. Sci. 30th Meeting, p. 70. 1909.

[2] 1 micron = .00003937 inch.

[3] ROBERTSON. Chemical Basis of Growth and Senescence. J. B. Lippincott Co., Philadelphia. 1923.

[4] BRODY AND RAGSDALE. Mo. Agr. Expt. Sta. Res. Bul. 67. 1924.

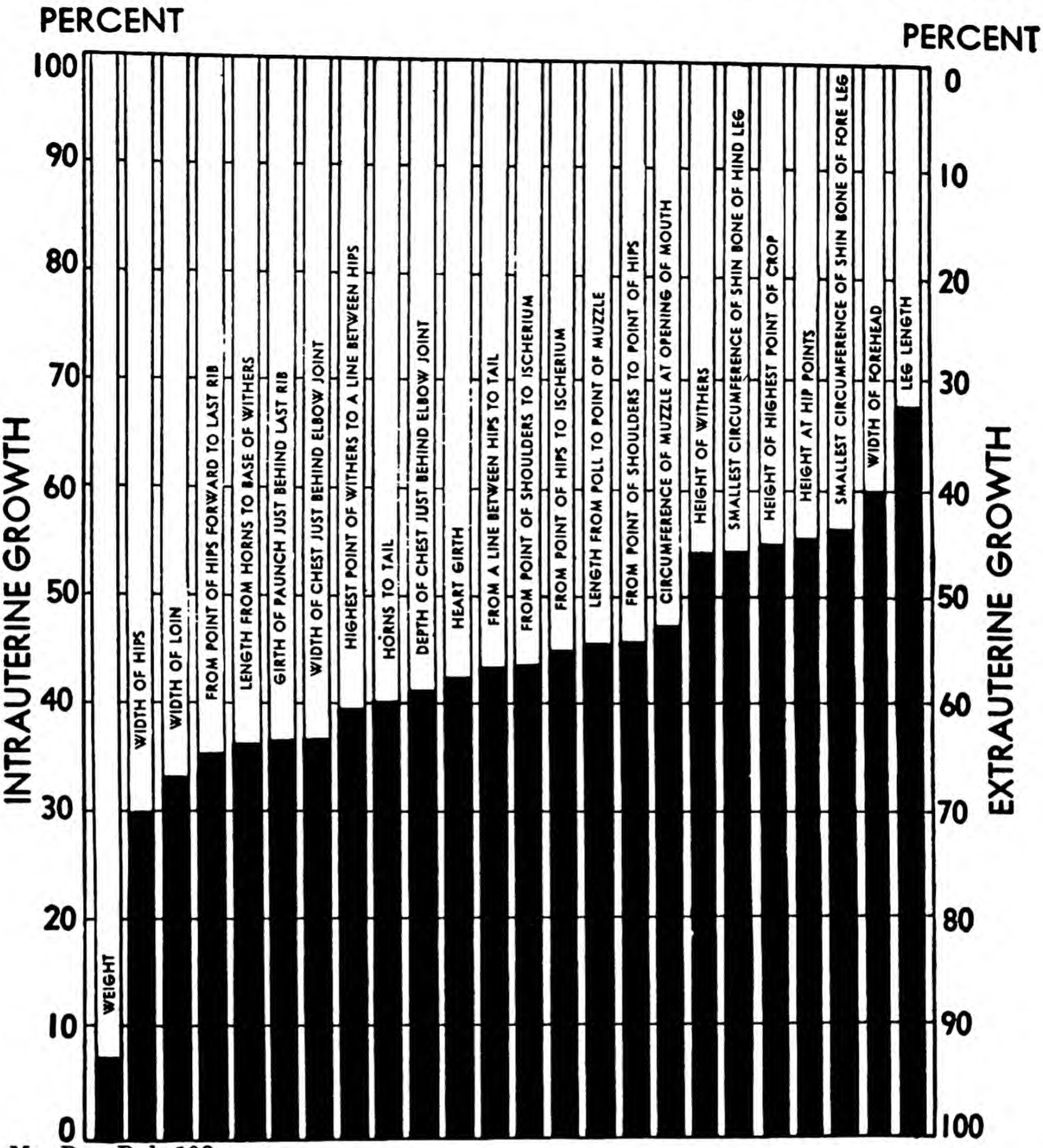
[5] BRODY. Mo. Agr. Expt. Sta. Res. Bul. 103. 1927.



Mo. Res. Bul. 67

Fig. 62. Change in form with maturity. The comparisons are based on enlarging the calf to equal the heifer in height at the withers in the top and the cow in the bottom illustration. In the middle the heifer is compared to the cow.

throughout life, such as hair, horn, and hoof. The sex organs make their major development just before and during puberty, and the mammary gland develops and involutes with successive gestation and lactation periods.



Mo. Res. Bul. 103

Fig. 63. The relative development of different anatomical parts of the bovine at birth expressed in percentage of mature values.

Changes in composition with age. Moulton has summarized the chemical analysis of cattle in various stages of development.[1] The main characteristic change in composition is loss of water from the tissues with age development. The early embryo contains as much as 95 per cent or more of water (on a fat free basis). At birth this has decreased to 75 or 80 per cent, and at 150 days it has decreased to about 73 per cent. From this point the water content from the body decreases until the minimum of 70 to 71 per cent is reached. Nitrogen rises from less than ½ per cent in the early embryo stage to 3 per cent at birth. It then rises rather rapidly

[1] Moulton. Jour. Biol. Chem. 57: 79–97. 1923.

to 3.6 per cent at ten months of age and is constant from this point on. Ash rises from .5 of a per cent in the early embryo to 4.3 per cent at birth; it increases to 5 per cent at five months and to 5½ to 6 per cent when mature. (All of the preceding figures are on a fat-free basis.)

Measures of growth. There is no absolutely satisfactory measure of growth known. In the early embryological stages cell number is the method resorted to in determining development. After that, weight and dimensional measures are the only ones used. Weight is most commonly used and may or may not be truly indicative of the degree of growth, since there are a number of factors other than growth that influence weight. The amounts of water and feed in the digestive tract vary greatly and influence weight. A difference of 50 pounds in the weight of a mature animal because of this factor is not uncommon. Because there is a great variation in daily weights, it is customary to weigh experimental animals for three consecutive days and use the average of the three weights. There are factors affecting the amount of water in the tissue which may influence the weight without any effect on growth. Fattening produces weight increases by a deposit of fat and a reduction of the amount of water. Starvation produces a loss in weight through a withdrawal of the fat stores. While the latter two affect weights markedly, neither can be said to be strictly growth phenomena. There may be growth without any change in weight. Waters maintained a steer at a constant weight for one year and found that it grew taller at the expense of body depth. For dimensional measurements the height at the withers is most commonly used. Attention is called to the practical difficulties in determining the height at the withers. The posture of the animal at the time the measurement is taken affects very materially that measurement. Usually the height at the withers is measured three times. The animal is moved immediately preceding the taking of the measurement. Dimensional measurements are less sensitive than weights. For cattle a 40 per cent increase in weight is usually accompanied by not more than a 10 per cent increase in the height at the withers. In studying growth in cattle it is customary to take both weight and height at the withers.

Rate of growth. The rate of growth changes with the age of the animal. If the rate of growth is expressed in gains for a definite period of time, such as daily gains or weekly gains, there is an increase until the end of the self-accelerating period, and then a decrease until growth ceases. If the rate of growth for any period is expressed in terms of per cent increase in weight of the animal, the values decrease with age. If the rate is expressed by merely giving the total weight or height of the animal for the different ages, then there is an increase until growth ceases.

Per cent gain in terms of total body weight is a measure of the intensity of the growth impulse. This impulse is the greatest immediately after fertilization, when the weight increase may be as great as 1,000 per cent for one day. At birth about 98 per cent of the growth impulse is lost. That daily gains increase with advance in age up to a maximum with a decrease in growth impulse is accounted for by the great increase in the number of

NORMAL GROWTH FIGURES FOR FEMALES *

Age	Ayrshire		Guernseys		Holstein		Jerseys	
	Weight	Height at Withers	Weight	Height at Withers	Weight	Height at Withers	Weight	Height at Withers
Months	*Pounds*	*Inches*	*Pounds*	*Inches*	*Pounds*	*Inches*	*Pounds*	*Inches*
Birth	72	27.6	65	26.6	90	29.1	53	25.7
1	89	28.6	77	28.2	112	30.6	67	27.0
2	119	30.2	102	29.8	148	32.3	90	28.9
3	158	31.9	133	31.6	193	34.3	121	30.6
4	198	34.0	173	33.5	243	36.2	158	32.6
5	245	35.5	216	35.3	297	37.7	199	34.5
6	293	37.2	260	36.9	355	39.7	243	36.2
7	344	38.5	305	38.4	410	41.1	286	37.7
8	389	39.9	350	39.9	462	42.3	324	39.0
9	433	40.9	389	40.9	509	43.5	360	40.1
10	469	41.7	427	41.7	552	44.4	393	40.9
11	502	42.5	459	42.6	593	45.3	420	41.7
12	538	43.2	490	43.3	632	46.0	450	42.2
13	577	44.0	524	43.9	671	46.7	479	42.8
14	611	44.8	556	44.6	705	47.3	507	43.3
15	638	45.1	584	45.0	746	47.9	530	43.9
16	669	45.7	605	45.3	782	48.5	558	44.4
17	697	46.2	634	45.9	809	48.9	580	44.7
18	725	46.5	663	46.4	845	49.3	601	45.2
19	758	46.8	686	46.7	878	49.8	622	45.5
20	793	47.4	712	47.0	912	50.2	642	45.9
21	818	47.6	737	47.3	952	50.6	665	46.2
22	844	47.8	763	47.7	986	51.0	684	46.4
23	871	48.1	788	47.9	1,024	51.3	708	46.7
24	902	48.3	818	48.0	1,069	51.7	733	46.9
27	909	48.1	876	48.9	1,151	52.2	816	47.7
30	945	48.3	880	49.3	1,120	52.5	824	47.9
33	965	48.9	905	49.7	1,130	52.7	832	48.0
36	968	48.7	901	49.9	1,165	53.0	855	48.2
39	1,007	49.1	924	50.0	1,176	53.1	899	48.6
42	1,014	49.9	952	49.9	1,202	53.2	895	48.6
45	1,038	50.0	971	50.1	1,197	53.2	898	48.5
48	1,035	50.2	990	50.4	1,232	53.3	897	48.5
51	1,040	49.4	980	50.6	1,261	53.5	927	48.5
54	1,058	50.3	1,024	50.5	1,271	53.6	952	48.6
57	1,073	50.3	1,031	50.5	1,305	53.7	944	48.6
60	1,080	50.4	1,055	50.6	1,330	53.6	937	49.0
63	1,037	49.2	1,043	50.4	1,310	53.5	948	49.0
66	1,055	49.2	1,051	50.0	1,312	53.7	955	48.7
69	1,088	49.3	1,073	49.8	1,343	53.7	966	48.6
72	1,132	49.1	1,093	49.7	1,317	53.7	973	48.4
75	1,067	48.3	1,042	49.3	1,320	53.9	964	48.5
78	1,080	48.9	1,084	49.4	1,357	54.0	998	48.6
81	1,092	49.1	1,071	49.2	1,400	53.8	991	48.4
84	1,122	48.7	1,066	49.3	1,401	53.7	959	48.0
87	1,109	48.8	1,065	49.4	1,402	53.6	952	48.3
90	1,103	48.7	1,053	49.4	1,358	53.7	1,002	48.2
93	1,083	48.5	1,067	48.9	1,335	53.5	984	48.4
96	1,143	49.2	1,070	49.6	1,365	53.2	909	47.7

* BOWLING AND PUTNAM (W. Va. Agr. Expt. Sta. Circ. 79) give tables of Ayrshire females to 96 months that are slightly lower at birth and slightly higher at older stages.

NORMAL GROWTH FIGURES FOR MALES *

Age	Ayrshire		Guernsey		Holstein		Jerseys	
	Weight	Height at Withers	Weight	Height at Withers	Weight	Height at Withers	Weight	Height at Withers
Mos.	*Pounds*	*Inches*	*Pounds*	*Inches*	*Pounds*	*Inches*	*Pounds*	*Inches*
Birth	81	27.9	71	27.7	94	29.4	60	26.2
1	101	29.4	87	29.3	125	31.2	78	27.9
2	133	30.9	113	30.6	164	33.2	104	29.7
3	173	32.7	147	32.4	214	34.8	141	31.5
4	217	34.5	190	34.2	269	36.4	184	33.6
5	267	36.1	237	36.1	336	38.8	233	35.5
6	321	37.9	291	37.8	399	40.5	282	37.2
7	378	39.4	345	39.2	456	41.9	326	38.4
8	433	40.7	401	40.3	514	43.1	371	39.5
9	488	41.8	443	41.5	563	44.2	410	40.4
10	536	42.7	494	42.5	620	45.1	452	41.4
11	601	44.1	547	43.3	683	46.4	497	42.7
12			609	44.5	741	47.5	531	43.0
13					796	48.2	566	43.9
14					870	48.8	613	45.0
15					978	49.7	643	45.5
16					1,035	50.5	679	46.1
17					1,090	50.7	726	47.0
18					1,176	52.2	745	47.5
19					1,236	53.3	826	48.4
20					1,286	53.3	856	48.6
21					1,345	54.3	875	48.9
22					1,364	54.3	904	49.3
23					1,410	54.9	931	50.0
24					1,438	55.9	969	50.3

* BOWLING AND PUTNAM data (W. Va. Agr. Expt. Sta. Circ. 79.) gives birth wts. of 76 pounds and height at withers of 27.4 inches. At 12 months these figures are 657 and 44.5 respectively.

cells. The growth impulse, therefore, does not decrease as rapidly as the number of cells increase until after the self-inhibiting period has been reached. For differences in the rate of growth of prenatal and extrauterine refer to Figure 63.

Normal growth curves. The normal growth figures have value as a guide in determining whether or not animals are doing as well as they should. They are of particular value for the experimentalist who is anxious to know whether a particular ration or type of experiment affects the normal growth of the animal. The normal growth figures for the four dairy breeds as computed by the Missouri Experimental Station [1] are given in the two tables on pages 000 and 000. These figures were gathered from Missouri, Kansas, and Iowa. Attention is directed to the fact that there are great variations from the figures given as normal. Because they represent averages in different sections of the country, perhaps different

[1] RAGSDALE. Mo. Agr. Expt. Sta. Bul. 336. 1934.

sets of normal figures should be given. Attention is also directed to the fact that growth in weight continues until past seven or eight years, while maximum height at withers is attained somewhat earlier. Comparing the normal growth figures for bulls with those of females, it will be noted that the bulls make more rapid growth than the heifers.

Heartgirth and body weights. There is a sufficiently good correlation between the heartgirth and body weight that this measure may be used for reasonably close estimates of weight of cattle. Estimations made by this method are most accurate for cows but may be used for heifers and calves. The measurement should be taken immediately back of the elbows. The weights for various heartgirth measurement in inches prepared by the Bureau of Dairy Industry, U.S.D.A., are given in the following table:

HEARTGIRTH MEASUREMENTS FOR DETERMINING BODY WEIGHTS OF DAIRY COWS

Heart-girth	Body weight	Heart-girth	Body weight	Heart-girth	Body weight	Heart-girth	Body weight
inches	*pounds*	*inches*	*pounds*	*inches*	*pounds*	*inches*	*pounds*
26	80	42.5	248	59.5	622	76.5	1,263
26.5	82	43	257	60	637	77	1,285
27	84	43.5	266	60.5	652	77.5	1,308
27.5	86	44	275	61	668	78	1,331
28	89	44.5	284	61.5	684	78.5	1,354
28.5	92	45	294	62	700	79	1,377
29	95	45.5	304	62.5	716	79.5	1,400
29.5	98	46	314	63	732	80	1,423
30	101	46.5	324	63.5	749	80.5	1,446
30.5	104	47	334	64	766	81	1,469
31	108	47.5	344	64.5	783	81.5	1,492
31.5	113	48	354	65	800	82	1,515
32	118	48.5	364	65.5	817	82.5	1,538
32.5	123	49	374	66	835	83	1,561
33	128	49.5	384	66.5	853	83.5	1,584
33.5	133	50	394	67	871	84	1,607
34	138	50.5	404	67.5	889	84.5	1,630
34.5	143	51	414	68	908	85	1,653
35	148	51.5	424	68.5	927	85.5	1,676
35.5	153	52	434	69	947	86	1,699
36	158	52.5	445	69.5	967	86.5	1,722
36.5	163	53	456	70	987	87	1,745
37	168	53.5	467	70.5	1,007	87.5	1,768
37.5	174	54	478	71	1,027	88	1,791
38	180	54.5	489	71.5	1,048	88.5	1,814
38.5	186	55	501	72	1,069	89	1,837
39	192	55.5	513	72.5	1,090	89.5	1,860
39.5	200	56	526	73	1,111	90	1,883
40	208	56.5	539	73.5	1,132	90.5	1,906
40.5	216	57	552	74	1,153	91	1,929
41	224	57.5	565	74.5	1,175	91.5	1,952
41.5	232	58	579	75	1,197	92	1,975
42	240	58.5	593	75.5	1,219	...	....
...	...	59	607	76	1,241	...	....

Limits of growth. As stated before, each individual inherits a limit beyond which an amount of feed or care will permit it to grow; but whether a limit of growth is reached depends upon a number of environmental factors. A knowledge of these factors is of mere academic interest, but many of them are of great importance in the practical phases of raising dairy cattle. The factors influencing the size of the calf at birth and the effects of breed, gestation, lactation, nutrition, and others upon growth and ultimate size will be considered.

Factors influencing size of calf at birth. The size of the calf at birth is dependent more on inheritance than on any other factor. In general, the larger the breed the larger will be the calf at birth. This is brought out in the following table, which gives the average weights and height at the withers of calves at birth for the different dairy breeds.

Individual variation is the next biggest factor which affects the birth weight of calves. Jerseys, for instance, may vary from 35 pounds to 90 pounds; and Holsteins vary from 40 to 140 pounds. The age of the dam affects the size. The first calf is usually three or four pounds smaller than the second calf, and the third calf is one or two pounds larger than the second. In extreme old age the calves are generally smaller. Contrary to popular opinion, the condition of the dam has no effect upon the birth weight of the calf unless extreme inanition or nutritional deficiency is manifest. In some cases of vitamin A deficiency the calves may be materially reduced in size at birth.

Average Heights and Weights at Birth for Calves of the Different Breeds

Breed	Heifers		Bulls	
	Weight	Height	Weight	Height
	Pounds	*Inches*	*Pounds*	*Inches*
Ayrshire	72	27.6	81	27.9
Guernsey	65	26.6	71	27.7
Holstein	90	29.1	94	29.4
Jerseys	53	25.7	60	26.2
Shorthorn	73		74	
Brown Swiss	80		85	

Sex of the calf is another factor affecting size at birth. Male calves average from five to ten pounds more at birth than do female calves. The length of the period of gestation also influence birth weights. Prematurely born calves are much smaller than those carried to full term.

Breed as a factor. Each breed has a characteristic norm for growth and development. From birth to 24 months of age the Holstein (See tables pages 280 and 281) increased 23 inches in height at the withers and gained 948 pounds, as contrasted to an increase of 21.4 inches and a gain of 753 pounds for Guernseys in the same length of time. Referring to the tables, it will be seen that the Jerseys reach maturity earlier than the Holsteins.

It is reported that the Jersey has reached skeletal maturity within three to four years, while the Holstein requires four to five years to do this. The maximum weights are reached usually about two years following the cessation of skeletal growth.

Effects of gestation. Contrary to popular opinion, gestation does not affect the rate of growth to any extent. In 1891 Minot reported that pregnant guinea pigs gained more rapidly than farrow ones. Eckles[1] found no increase in the nutrient requirements for pregnant cows. That there should be no great demand is evidenced by the small amount of dry matter in the calf at birth. Missouri Station workers have shown that only 26 to 28 per cent of the birth weight of a calf is dry matter.[2] Therefore, there is no more dry matter in a Jersey calf at birth than there is in 100 to 180 pounds of milk. In the case of Holsteins 200 to 275 pounds of milk contain as much dry matter as is found in the calf at birth. It has also been observed that when heifers were dried off immediately after calving, there was no effect upon the growth rate.

Effect of lactation. As contrasted to the effects of gestation, lactation has a very marked effect upon the rate of growth. In the young dairy animals lactation slows up and sometimes completely stops growth in both height and weight. This is the main reason for desiring size in heifers before the first calving. The reason that lactation stops growth is evident when it is considered that two pounds of daily gain in body weight contain 1.5 pounds of dry matter. Eleven and one-half pounds of milk containing 4 per cent fat also contain 1.5 pounds of dry matter. A heifer producing 40 pounds of 4 per cent fat milk produces 5.2 pounds of dry matter or approximately three times as much dry matter as would be produced in a good daily gain for a growing heifer. It is the demand for the nutrients to make milk that prevents growth.

The age of first calving affects both the rate of growth and the ultimate size obtained. As just noted, lactation demands so much nutrient that the animal is unable to consume sufficient feed to supply the needs of both milk production and body growth. In the dairy animal, with the tendency for milk production so strongly inherent, growth suffers first. Immature animals in milk may be developed into normal size provided they are given long rest periods. It is far better that the heifers be grown to a good size before coming into milk.

Effect of nutrition. It is well known that body tissues have their origin from the feed consumed. It is therefore only reasonable that the amount of feed and the kind of feed consumed should affect growth. Growth can be speeded up very materially by liberal feeding. There are, however, definite limits to this: first, in the amount of feed that the individual animal can handle, and second, in the amount of growth stimulus that is released by the animal over a given period of time. Growth can be checked very materially by withholding feed. Waters maintained a steer

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[1] Eckles. Mo. Agr. Expt. Sta. Res. Bul. 26. 1916.
[2] Haigh, Moulton, and Trowbridge. Mo. Agr. Expt. Sta. Res. Bul. 38. 1920.

at constant weight for one year.[1] Afterwards this steer was fed liberally, and in one year's time it became normal in size. Apparently different stimuli for growth had accumulated, and when the opportunity came the steer responded in unusually rapid growth. Many people recognize the fact that animals whose growth has been retarded through subnormal nutrition will make much more rapid gains on good feed than will animals of the same size whose ration has been normal.

Effect of nutrition on dairy type and quality. The general belief that fat heifers develop into poor dairy animals is not substantiated in its entirety by facts. Eckles did find that if heifers were fed light rations during their growing period, they produced slightly more butterfat in the second lactation periods than those that were heavily fed.[2] However, the heavily fed heifer produced more than the lighter fed heifer in the first lactation period. The variability in the production of individuals is great enough to account for the difference in average production of the two groups, and this evidence must not be taken as conclusive.

Factors influencing sexual maturity. Breed is one of the chief factors affecting the age at which an animal comes to sexual maturity. In general, the earliness of sexual maturity is inversely related to the size of the breed, the Jersey reaching sexual maturity the earliest, and the Brown Swiss the latest of the dairy breeds. There are individual variations within the breed that can be accounted for by inheritance. Nutrition is also an important factor; liberal feeding is responsible for earlier sexual maturity. The Missouri Station found that lightly fed Holstein heifers became sexually mature on an average of 273 days of age, while the heavily fed ones did so in 261 days of age. At the Minnesota Station it was noted that animals on a phosphorus deficient ration became sexually mature at a much later date than those having a nutritionally complete ration.

[1] WATERS. Proc Soc. Prom. Agr. Sci., 29th meeting, p. 71. 1908.
[2] ECKLES. Mo. Agr. Expt. Sta. Res. Buls. 24 and 25. 1916.

Chapter 29

CALF RAISING

CALF RAISING IS AN IMPORTANT PROBLEM ON THE DAIRY FARM. IN PURE-bred herds all calves are raised; in others sufficient numbers must be raised to replace cows that go out of the herd. In addition to that, large numbers of calves are raised annually for veal. On an average a cow's production life is about four years. With 25,000,000 cows in the United States according to the 1948 estimate 6,000,000 calves must be raised annually to replace the cows going out of production. Thus, two heifers must be raised annually per eight cows. In order to have two heifers come into production for each eight cows, at least six must be raised for each twenty cows. Since many dairymen sell whole milk and do not attempt to raise calves, others must raise more in order to supply these dairies with milking stock. Approximately 4 per cent of the whole milk produced in the United States is fed to calves. In 1947 this amounted to over 4,500,000,000 pounds. An important consideration in calf raising is that of avoiding the introduction of diseases. By depending upon the purchase of milk cows to replenish those that go out of the herd, there is great danger of introducing one or more of the many infectious diseases with which cattle are afflicted. A good dairyman, therefore, takes the job of raising calves as an important one.

SELECTING CALVES

Since the cost of raising calves to maturity is a considerable item of expense on the dairy farm, only those calves that give indications of growing into profitable cows should be selected. Only by careful selection of calves from high producing dams and families having the desired characteristics can one develop a superior herd. Not always can the mature abilties of a calf be predicted, for the type of the calf is not a reliable indication of the type of cow it will grow into when mature; but when one uses judgment in selection, a much smaller percentage of unsatisfactory mature cows will be raised. Special consideration should be given to the height of production of the dam and her immediate family, and to the strength and vigor of the calves at birth. Weak calves are likely to succumb to the various calf diseases that are encountered. If one has a herd that produces milk of too low a fat percentage, special effort should be made in selecting the calves from the lines that have a high fat content milk. Any other desirable characteristic that one wants in a good cow should be taken into consideration when one selects calves to be raised to maturity.

NUTRIENT REQUIREMENTS

The solution of many of the different problems encountered may be found in the knowledge of the fundamental requirements for growth and development of the calf. The newer knowledge of nutrition has added

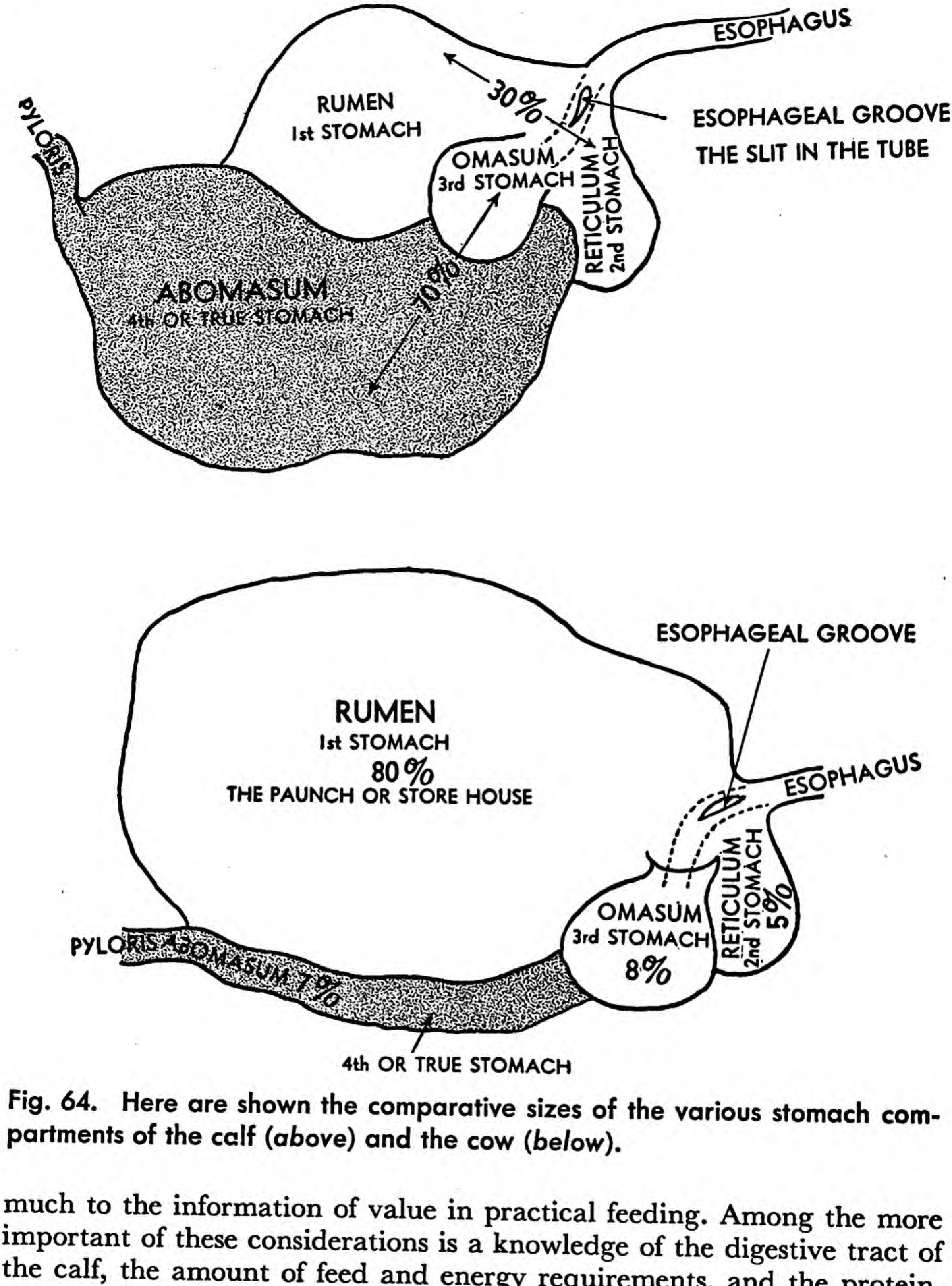

Fig. 64. Here are shown the comparative sizes of the various stomach compartments of the calf (*above*) and the cow (*below*).

much to the information of value in practical feeding. Among the more important of these considerations is a knowledge of the digestive tract of the calf, the amount of feed and energy requirements, and the protein, mineral, vitamin, and water requirements.

Digestive tract. A knowledge of the structure of the digestive tract of the calf will help one to appreciate the necessity for certain types of rations. The digestive tract of the calf differs from that of the cow in its proportionate size and in the different proportions of the stomach compartments. (Fig. 64.) In the mature animal, the rumen occupies 80 per cent of the total capacity of the stomach; the abomasum and omasum

each occupy from 7 to 8 per cent. In the young calf, the abomasum and the omasum are two times as large as the rumen and reticulum combined. These proportions change rapidly with the advance in age. In the calf of ten to twelve weeks of age, the omasum and the abomasum are only half the size of the rumen and the reticulum. At one year, these proportions have shifted to that of the mature animal. Very little definite information is available as to the exact capacity of the abomasum. This is the true stomach, where the digestion takes place. Milk goes directly into the abomasum under normal conditions. However, if more milk is consumed than the abomasum has capacity for, then it may pass directly into the rumen. As the young calf has no powers for regurgitation, the material may decompose in the rumen and cause digestive disturbances. Some authors claim that the maximum capacity of the abomasum in the young calf is two quarts, and for the whole stomach, less than one gallon. The mature animal of medium size has a total stomach capacity of from 30 to 40 gallons. Large animals may have a capacity as high as 75 gallons. It is therefore apparent that with the development of the calf to maturity the stomach grows more rapidly than the rest of the body.

Amount of feed and energy. Because of the small digestive storage facilities, the calf cannot handle much food at a time. It cannot use roughage to any great extent until five or six months of age, and not until ten months of age could even a vigorous calf exist on roughage alone. Energy must come from milk or concentrates. Morrison, an eminent authority on feeding, places the total digestive nutrient requirements at from 1.5 to 2.2 pounds for a calf weighing 100 pounds. For a 1,000 pound calf, the requirements are 11.4 to 12.6 pounds. Therefore, the requirements per pound of live weight are greater for the young calf than for the older one.

Protein requirements. The protein content of the calf's body increases rapidly up to six months of age through both an increase in the percentage amount in the body and the increase in weight. The relative protein requirements are, therefore, the highest during the first few months of a calf's life. Morrison, after reviewing all experimental work, recommends a nutritive ratio of 1:3.9 to 1:4.5 for calves at 100 pounds of live weight; this gradually widens until at 1,000 pounds the recommended ratio is 1:8.2 to 1:8.4.[1] The quality of the protein is of great importance. There is no better source of protein than milk. When milk substitutes are used, careful attention must be paid to the types of protein as well as to the total amounts. Calves fed whey suffer probably both from an insufficient amount of protein and from an inadequate quality of protein.

Mineral requirements. Like the protein parts of the body, the skeleton grows relatively most rapidly in the early ages of the calf. The per cent of ash rises rapidly up to 5 months of age. As the major portion of bone consists of calcium and phosphorus salts, the calcium and phosphorus supplies in the diet must be adequate. Milk supplies these important mineral elements in ample amounts. However, after calves are weaned,

[1] MORRISON. Feeds and Feeding. Morrison Pub. Co., Ithaca, N. Y. 1936.

the ration is frequently inadequate in its calcium and phosphorus content. Iodine is adequate in most normal rations; however, in some iodine deficiency areas, the feeds lack sufficiently in this element to produce deficiency symptoms. If the calves have goiter when they are born, it is an indication that the iodine supply is inadequate. It should be supplied to the cows in the form of iodized salt, which is an adequate source of this mineral element. Iron and copper are both needed for the production of red cells in the blood. Milk under all conditions is deficient in these two elements, and calves fed on milk alone develop anemia. When calves are fed grain and hay in conjunction with milk, there is no danger of insufficient iron and copper.

Magnesium. Milk is relatively low in its magnesium content. Calves that are fed on milk only, sooner or later develop spasms, to which they finally will succumb. The Michigan [1] and Minnesota [2] Stations have recently found that the magnesium content of the blood drops previous to the onset of the spasms. Hay and grain contain adequate magnesium and will prevent the difficulty encountered when milk only is fed. The Wisconsin Station suggests that manganese may be an element needed in the raising of calves, and that milk is deficient in this element. The evidence at this time is not sufficient to warrant drawing definite conclusions.

Sodium chloride. Sodium chloride, or common table salt, should be furnished calves at all times. It is particularly essential that salt be furnished when the calves begin to eat grain and hay. The failure of supplying salt at this stage frequently results in unthrifty calves.

Vitamin requirements. As yet the extent to which vitamins are essential in the raising of dairy calves is not definitely known. Some, such as vitamins B and C, are definitely known not to be required. However, vitamins A and D may be important factors in some of the diseases encountered in dairy calves. The amounts of vitamins A and D in the milk depend upon the amount present in the feed that the cow consumes. Recently it has been shown by the United States Department of Agriculture and the California Station that calves may suffer from a vitamin A deficiency under practical conditions. Converse and Meigs [3] fed cows on ripe timothy hay for the entire year, and the calves were either born dead or died on the skim milk diet from such cows. They attributed this difficulty to the vitanmi A deficiency in the diet of the cows. Hart and Guilbert,[4] studying the calf diseases on the range, found many calves suffering from what they diagnosed as vitamin A deficiency. They reported that vitamin A deficiency of the diet of the dams is responsible for calves that are weak at birth and that develop severe diarrhea. One of the characteristic symptoms of this deficiency is eye lesions. The Minnesota Station [5]

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[1] Duncan, Huffman, and Robinson. Jour. Biol. Chem. 108:35–44. 1935.
[2] Wise. Doctor's Dissertation, Univ. of Minnesota. 1937.
[3] Converse and Meigs. Holstein-Friesian World 32:80. 1935.
[4] Hart and Guilbert. Calif. Agr. Expt. Sta. Bul. 560. 1933.
[5] Thurston et al. Jour. Dairy Sci. 9:37–49, 1926, and 12:394–404, 1929.

was the first one to produce vitamin A deficiency in calves; but, finding difficulty in preparing a diet sufficiently low in this factor to produce definite symptoms, naturally concluded that under normal conditions vitamin A deficiency would not be expected in dairy calves. Frequent reports of symptoms analogous to vitamin A deficiency would lead one to suspect that this deficiency is far more common throughout the country than has been heretofore suspected.

While the mature bovine synthesizes all of the vitamin B complex and vitamin E the young calf is incapable of doing so and must depend upon body stores at birth and its food for sources of these vitamins. One of the B complex (niacin) is synthesized by the young calf. The rest of the B complex that is needed for the bovine species are synthesized in the rumen by microorganisms present therein. This synthesis does not begin until the rumen becomes functional after consumption of roughage.

While it is possible for a young calf to be deficient in the vitamin B complex it is doubtful that it occurs on farms at least where calves receive colostrum and milk up to four weeks of age. Colostrum is not only rich in vitamin A but also in the B complex as compared to normal milk. Extensive experiments [1] where calves were fed vitamin supplements have shown no lessening in calf digestive upsets nor mortality.

Vitamin A supplement [2] in the form of fish liver oils is beneficial when the diet of the pregnant cows is deficient in carotene and also in some cases of scours. For the most part, however, other causes for scours than vitamin deficiency must be looked for.

Water. Contrary to popular opinion, even when getting large amounts of milk the calf needs water in addition, particularly during warm weather. For successful calf raising, clean water should be available at all times. When calves have not been given water in addition to the milk for a long period of time, they are likely to drink too much when allowed unlimited quantities for the first time.

METHODS OF RAISING CALVES

Calves may be raised by hand or allowed to run with the dams. On the dairy farm practically all calves are raised by hand. Only on rare occasions, when a purebred calf is of unusual value, is it permitted to run with a nurse cow. In the feeding of calves on the dairy farm several different problems are encountered because of different conditions. Where butterfat is sold, adequate amounts of skim milk are available, and calf raising is comparatively easy. Where whole milk is sold, it is necessary to use milk substitutes in order to reduce the expense. In cheese-producing territories whey is sometimes available instead of skim milk, and another feeding problem is created.

Starting the calf. Regardless of the method used for feeding, the calf is started in the same way. Since it is important that the calf get colostrum, it should be left with the dam preferably for two or three days. If the

[1] Gilmore, Jones, Kanegis, and Roepke. Jour. Am. Vet. Med. Assoc. 110:390. 1947.
[2] Hibbs and Krauss. Jour. Dairy Sci. 30:115. 1947.

dam's udder is inflamed, it may be advisable to leave the calf and dam together for a longer period of time. Many dairymen are of the opinion that the calf assists materially in reducing udder inflammation. The importance of colostrum to the young calf has been recognized for a long time, but only recently has the real reason for this need been discovered.[1] Smith and Little found that calves not receiving colostrum were far more susceptible to infections, particularly of the digestive tract, than those that were fed colostrum.[2] The mortality resulting from these infections was exceedingly high, and *B. coli* were found in the bodies of the dead calves. Ragsdale and Brody, too, found that calves fed colostrum had a much better chance of survival and suffered less from calf diseases than those not receiving colostrum.[3] Colostrum assists in the prevention of diseases, according to Smith and Little, because of its antibody content. They found that at birth the animal had no agglutinins in the blood and within a matter of hours following the ingestion of colostrum agglutinins appeared.

Colostrum differs from normal milk in more than its antibody contents. It has ten or more times as much vitamin A, depending upon the carotene or vitamin A content of the pregnant cow's ration. It contains about twice as much dry matter. Protein content is about 18 per cent compared to 3.5 per cent for normal milk. Most of the protein is in the form of globulin the fraction containing the antibodies. Colostrum contains about five times as much tocopherol as normal milk, about 4 times as much riboflavin, twice as much thiamine, seven times as much choline and about twice as much pentothenic acid. In minerals colostrum also excels normal milk by twice as much calcium, phosphorus, sodium, and chlorine, and three times as much magnesium. It is also richer in potassium, iron, copper, and manganese than normal milk.

When cows are milked before delivery there will be no colostrum following parturition. In such cases other sources of colostrum must be provided or heavy losses in calves may be expected. One satisfactory method is to freeze the first few milkings when prepartum milking is begun, since this will be normal colostrum—provided there has been a sufficiently long dry period. In large herds it will often happen that colostrum will be available from newly freshened cows.

It is important that the first feed of the newborn calf be colostrum. At this time the intestinal wall is permeable to the globulin antibodies. After the first feed the intestines rapidly become impermeable to this material.

Teaching the calf to drink. Teaching the calf to drink out of a bucket is sometimes quite difficult. There are many contrivances on the market that are designed to aid one in teaching a calf how to drink. A number of them are effective, but there is the danger of these appliances becoming contaminated, with the ensuing danger of digestive disturbance in the calf. The natural way for the calf to get milk is by raising his head. The

[1] ROGERS AND ASSOCIATES. *Fundamentals of Dairy Science*. 2nd ed., pp. 466–474. Reinbold Pub. Co. 1935.
[2] SMITH AND LITTLE. Jour. Exptl. Med. 36:181–453. 1922.
[3] RAGSDALE AND BRODY. Mo. Agr. Expt. Sta. Bul. 197. 1922.

best way to teach a calf to drink is by the following method: First, let him go without food for 24 hours after taking him from the dam. Then insert the fingers of one hand into his mouth and gradually pull his muzzle down into the milk. For a large calf this requires considerable physical strength, but it can be effected by backing him into the corner of a pen and forcing his head down into the milk.

Amount of milk and frequency of feeding. Calves are more often overfed than underfed. Never should more milk be offered a calf per day than 8 per cent of the total weight of the calf. This means that a normal Jersey calf would not get more than five or six pounds of milk per day, and that a Holstein would be limited to a maximum of 8 pounds a day at the start. It is better to feed a calf three times a day than twice a day. The reason for limiting the amount of milk and for advocating more frequent feedings is that the capacity of the abomasum, the true stomach, is small, and when it is overloaded, one or both of two things may happen: (1) Part of the milk may pass into the rumen, where putrefaction will occur. (2) Because of a large amount of milk in the abomasum, a large curd is formed which is not completely digested before the next feeding, and putrefaction sets in. Autopsies on calves dying from digestive disturbances invariably reveal large curds in the true stomach and sometimes in the rumen. According to Sheehy [1] the putrefaction of curds either in the rumen or abomasum is the cause of most digestive disturbances in calves. Feeding smaller amounts of milk at more frequent intervals is the best method of preventing these disturbances. Diluting the milk with warm water at the rate of ⅓ water and ⅔ milk is advocated by some.

Nipple feeding. Recent studies on the entrance of milk into the stomach of the calf have shown that when milk is swallowed in large gulps such as occurs when drinking from a pail, part of it splashes into the rumen. Since this organ is nonfunctional in the young calf, the undesirability of getting milk therein is readily understood. The position of the head (whether high or low) when feeding from a pail makes no difference in the amounts that splash into the rumen. When calves are fed from nipple pails the amount of milk in each bolus was smaller than in the case of drinking from the pail, and no splashing into the rumen occurred. Many dairymen now feed calves by the use of nipple pails and report less difficulty from common scours.

The author and co-workers fed a limited number of calves by nipple, with milk before them at all times. The milk ranked in temperature from warm to near freezing. The calves consumed from two to three times as much milk per day as is usually considered safe when fed from pails twice daily, without any digestive upsets. The probable reason for freedom from digestive disturbances is the frequency with which they fed and the small quantities taken at each feeding. They consumed milk up to 17 times during a 24-hour period.

Raising calves on skim milk. While whole milk is the best feed, the fat of milk is too valuable to be fed to calves. Where butterfat is sold

[1] Sheehy. Royal Dublin Soc. Sci. Proc. (N.5) 21:73–85. 1934.

and skim milk is available, calves should be raised on skim milk, following the original whole milk period. Otis [1] demonstrated that while calves fed on skim milk did not make quite as large daily gains as those receiving whole milk, they gained more rapidly after weaning and made gains at much lower costs. This is shown in the following table, which

SKIM MILK COMPARED WITH WHOLE MILK AND RUNNING WITH DAM AS FEED FOR CALVES
(There were ten calves in each group. They were fed milk for 140 days, then transferred to a feed lot for 7 months.)

Results for 140 Days When on the Milk Diet

	Skim Milk	Whole Milk	Running with Dam
Average gain—lbs.	223	287	248
Average daily gains	1.51	1.86	1.77
Cost per 100 lbs. gain	$2.26	$7.60	$4.41

Results for 7 Months in the Feed Lot

Average gain—lbs.	440	405	422
Daily gains	2.10	1.93	2.00
Grain per 100 lbs. gain lbs.	439	470	475

contains a summary of Otis' work. This work has been corroborated by numerous other trials, in which calves raised on skim milk have been found to look rougher while on the skim milk diet than the calves on whole milk, and to make slightly less gains. They responded better on dry feeds following weaning, and matured as early and to as desirable animals as those raised on whole milk.

Changing from whole milk to skim milk. A healthy, vigorous calf may begin to receive some skim milk when two weeks old. The change from whole milk to skim milk should be gradual. One pound of skim milk should be substituted daily for one pound of the whole milk until the complete change is effected. Thus a calf getting ten pounds of whole milk would require ten days to be changed over to skim milk. This change is rather a critical time in the calf's life. Skim milk differs from whole milk in having the milk fat removed, the amounts of the other constituents thereby being slightly increased. By comparing the analysis of whole milk and skim milk given in the table on the next page, it will be seen that skim milk has slightly more than half of the total digestive nutrient that whole milk has, and that it has a much lower nutritive ratio, there being one pound of protein for each one and one-half pounds of nonprotein nutrients, as contrasted to a ratio of 1:3.9 for the whole milk. When he is changing to skim milk, the calf will be receiving far less energy, but a little more protein than when he is on the whole milk diet. It is, therefore, es-

[1] OTIS. Kans. Agr. Expt. Sta. Bul. 126.

sential that at this time a grain supplement be furnished to supply the additional needed energy. Corn alone is an adequate supplement; however, any ordinary grain mixture will suffice. Most calves will begin to eat grain at about two weeks of age, and little difficulty should be experienced in getting the calf to take the grain supplement at the time the change from whole milk to skim milk is completed. After the calf is on a skim milk diet,

AVERAGE COMPOSITION OF WHOLE MILK AND SKIM MILK

	Whole Milk	Skim Milk
Total solids	12.8	9.6
Protein	3.5	3.7
Fat	3.7	0.1
Sugar	4.9	5.0
Mineral	0.7	0.8
Total digestible nutrients	16.2	8.6
Nutritive ratio	1: 3.9	1: 1.5

the amounts of milk may be increased, but at no time should the amount of milk fed in one day exceed 10 per cent of the calf's weight. As the amounts of grain and hay consumed increase, it will be necessary to reduce the relative amounts of milk proportionately. At no time is it advisable to feed the calf more than 20 pounds of skim milk a day.

Raising calves where whole milk is sold. Where whole milk is sold, the problem of raising calves is different from what it is where there is skim milk available. Seldom are there enough calves, on a farm producing whole milk, to make it worth while to skim a portion of the milk for calf feeding. To solve the problem of raising calves under these conditions numerous experiments have been run at the various experiment stations in the United States. Various proprietary calf meals have also been prepared and are on the market as substitutes for milk. In attempts to develop satisfactory substitutes for skim milk scores of different mixtures have been tried. Cornell University reports excellent results with a calf meal made up into a gruel, replacing the whole milk on the twentieth day.[1] This mixture consists of:

500 lbs. yellow corn meal	200 lbs. soluble blood flour
440 lbs. red dog flour	20 lbs. calcium carbonate
300 lbs. oat flour	20 lbs. steam bone meal
300 lbs. linseed oil meal	20 lbs. salt

Animals raised on this calf meal have been carried through to the second year of milk production, and according to the report of the authors, no difference can be noted in their size or milk production from those raised on a skim-milk diet. The gruel was made by mixing the calf meal with

[1] MAYNARD, NORRIS, AND KRAUS. Cornell Agr. Expt. Sta. Bul. 439. 1925.

water at 100° F. in the proportion of one pound of gruel to five pounds of water.

The Oregon Station [1] tried three mixtures for calf meals. One of these consisted of:

Ground oats	150 lbs.
Ground yellow corn	150 lbs.
Wheat bran	150 lbs.
Linseed oil meal	50 lbs.
Soluble blood flour	50 lbs.
Steam bone flour	5 lbs.
Salt	5 lbs.

A second mixture contained 50 pounds of dried skim milk in place of the soluble blood flour, and a third contained 100 pounds of dried skim milk which replaced the blood flour, 30 pounds of ground oats, and 20 pounds of ground yellow corn. The three meals gave satisfactory results, the calves being slightly under the normal growth during the time that they received the calf meals; however, they soon caught up to normalcy. The third formula gave slightly better results than the first two; this is attributed to the high dry-milk content. These calf meals were fed dry, and the calves ate adequate amounts of them for sufficient nutritive intake. Many other stations have developed similar formulae and have reported similar successes. It may be said that if skim milk is available, it is preferable to calf meals for the raising of calves; but if skim milk is not available, the calf meals will prove satisfactory. While no definite experimental work is available on the comparative value of the proprietary calf meals, it may be said that many of them will give satisfactory results.

Raising calves on whey. In cheese-producing areas, whey is frequently available and can be used satisfactorily for calf feeding if the proper supplements are made. The Wisconsin Station has obtained good results by changing calves from whole milk to whey in the same way and at the same age as when the change was made from whole milk to skim milk.[2] They increased the whey allowance to 14 pounds when the calf reached six weeks of age. In cheese making most of the protein is taken out of the milk, and therefore the whey contains only 0.8 per cent protein, as contrasted to 3.7 per cent protein in skim milk. It is therefore necessary to feed a high protein grain supplement when whey replaces skim milk in calf feeding. At least 40 per cent of the concentrate should consist of linseed oil meal or soybean oil meal. The Wisconsin Station found a satisfactory mixture to be:

30 lbs. ground corn
30 lbs. standard wheat middlings
40 lbs. linseed oil meal

[1] Jones, Brandt, and Wilson. Ore. Agr. Expt. Sta. Bul. 290. 1931.
[2] Morrison, Hulce, and Humphrey. Wis. Agr. Expt. Sta. Buls. 339 and 362.

Since whey is obtained from cheese factories to which a number of farmers contribute milk, it is essential that the whey be pasteurized before it is returned to the farm, in order to guard against transmitting disease.

Raising calves on buttermilk. Frequently buttermilk is available at a reasonable price; then it will make an excellent substitute for skim milk. Buttermilk analyzes about the same as skim milk, and whether sweet or sour it can be substituted for equal quantities of skim milk. As it is frequently poorly cared for at the creameries, buttermilk from dirty storage tanks should not be used; it is certain to carry organisms that will produce digestive disturbances. While the cream from which the buttermilk comes is generally pasteurized in all creameries, before bringing the buttermilk to the farm one should make certain that either the cream or the buttermilk has been pasteurized; otherwise infectious diseases may be introduced into the herd.

Dried skim milk or buttermilk and semisolid buttermilk. Dried buttermilk or skim milk, when remade by mixing one pound of the dried product with nine pounds of water, makes up a solution of the same composition as liquid skim milk or buttermilk, and can be fed in the same proportions with the same results; or the dried products may be mixed with the grain and fed dry, one pound of the dry product being allowed where ten pounds of liquid skim milk or buttermilk would be used. Semisolid buttermilk is partially dried sour buttermilk prepared especially for livestock feeding. The Minnesota Station found that when this was allowed on the basis of the same dry matter content as in the normal liquid feeding, equally good results were obtained. The only objection to using these products is that frequently they are too costly. Sometimes drying plants have products that grade slightly below the requirement for human food; these products are sold at reduced prices and for calf feeding are equally as satisfactory as the better products.

Hay for calves. In raising a calf, hay is an essential in the diet. Calves on skim milk have an adequate amount of protein in the diet, and for them high quality grass hays, such as timothy or bluegrass, are preferable to legume hays. Legumes, however, are superior to the grass hay for calves on whey and on some of the calf meals. Legumes are characterized by very high protein and calcium content. The high protein content makes them suitable feed for calves on whey, and the high calcium content makes them a desirable roughage for calves on calf meals, as grains are low in calcium content.

A calf will usually begin to eat hay at about two weeks of age. It should be furnished fresh twice a day. Calves that do not receive hay are likely to suffer from vitamin D deficiency, particularly during the latter part of the winter or early spring, when milks are likely to be deficient in vitamin D and the sunshine is deficient in ultraviolet rays. Hays cured to the green color have far higher vitamin values than darker colored or bleached hays and are, therefore, to be preferred for calf feeding. Well-cured hays are also more palatable.

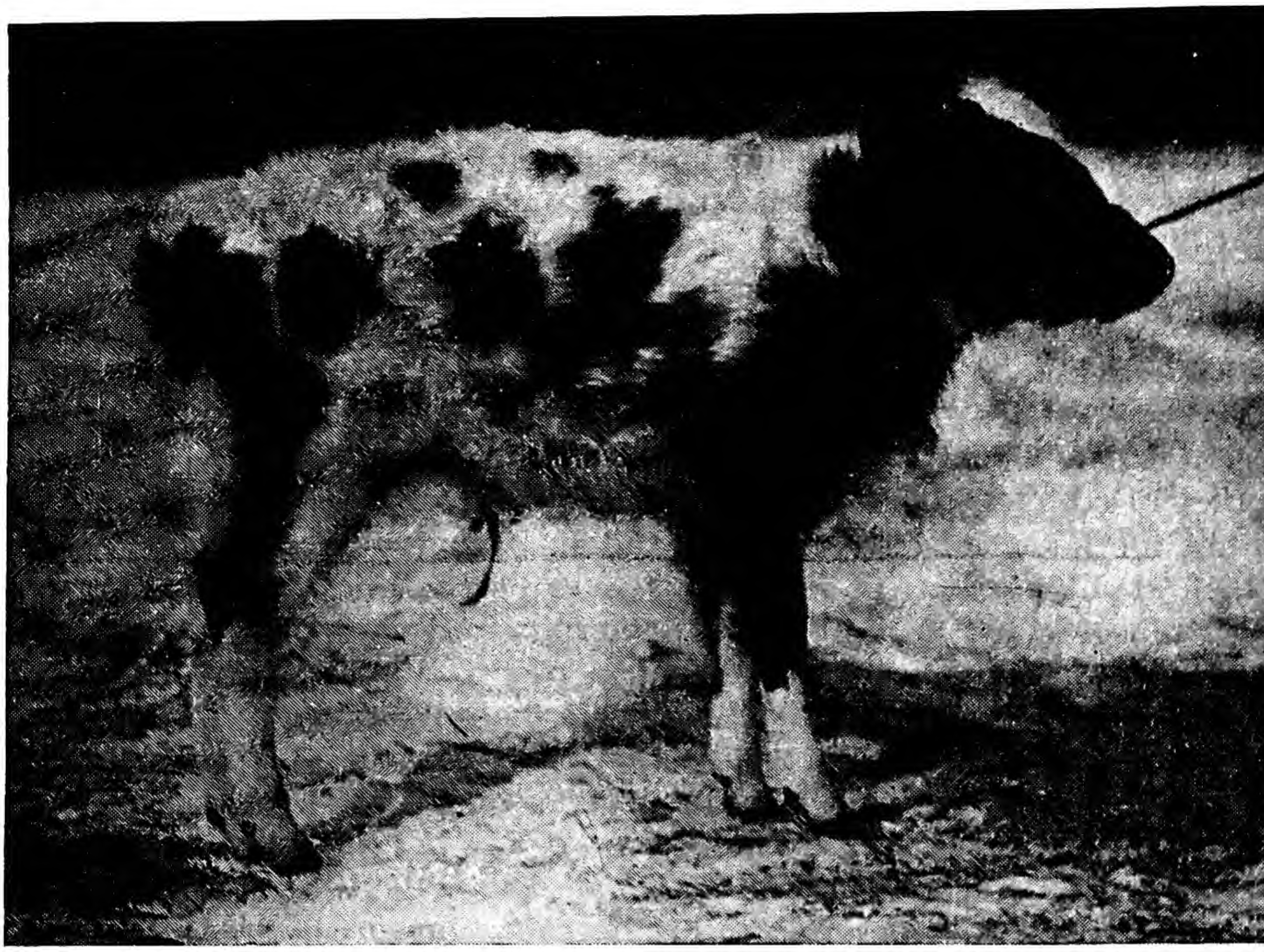

Fig. 65. An unthrifty calf. Its condition is due to malnutrition and disease.

Whole milk diet alone. While milk is considered the most nearly perfect food, it is inadequate for the complete nutrition of the dairy calf. Numerous attempts have been made at raising dairy calves on whole milk with various elemental supplements. Until recently, all such attempts have met with failure. At the Minnesota and Michigan Stations, calves have been raised to maturity on whole milk, with copper, iron, and magnesium supplements, plus cod-liver oil as a source of vitamins A and D. At the Minnesota Station, normal growth and normal reproduction have been experienced on such a diet. Unless copper and iron are added, the animal suffers from anemia and will ultimately succumb to that disease. Additional magnesium is needed in spite of the fact that milk contains fair quantities of that element. For some reason, not as yet entirely clear, the calf on a sole milk diet has a relatively high magnesium requirement.

Effect of foam in milk. It is generally assumed that foam, which is common in skim milk, is detrimental to the calves. The South Dakota Station [1] set up an experiment to determine the facts regarding foam fed to calves. Large quantities of separator foam were fed, and in no case was there evidence of any harmful effects from the ingestion of large amounts of it.

[1] Olson. S. D. Agr. Expt. Sta. Bul. 273. 1932.

Pasteurization of milk. The question would naturally arise as to whether pasteurization of milk would have any effect upon its nutritive value. The California Station [1] heated milk to 170° F. and could not detect any difference in the nutritive value for calf feeding between milk so heated and raw milk. In the common methods of pasteurization, vitamin C is destroyed. As the calf does not need vitamin C in the food, this would not be expected to impair the nutritive value of milk in any way.

Temperature of milk and cleanliness of utensils. In the early weeks of a calf's life, at least, the temperature of the milk should be around 100° F. when fed. After the calf becomes several months of age, this is not so important. Cleanliness of the utensils with which the milk comes in contact is of utmost importance. Milk is one of the best mediums for bacterial development, and in buckets and other utensils in which small portions of milk are left extensive bacterial development takes place. Many of the types of bacteria so developed when taken into the calf's digestive tract will produce putrefactive changes which, in turn, produce scours. The most serious digestive disturbance can frequently be attributed directly to failure to clean the milk buckets used for calf feeding. These buckets should be cleaned as scrupulously as any utensil with which milk for human food comes in contact.

Calf pens. The prime requisite of calf pens is that they furnish a light, clean, dry, and draftless place for the calf. One of the chief causes of calf pneumonia is dampness and draftiness, which are also conducive to calf scours. These two diseases cause the heaviest losses among calves. The ideal calf pen is the individual pen with solid partitions between neighboring pens, 3 feet by 6 feet in dimension. Infectious diseases are communicated by direct contact of calves, and this type of pen prevents such contacts. The solid partition has a tendency to prevent drafts from directly hitting the calf. In the colder climates, it is preferable to have the calf pens located in the cow barn; calves do not generate enough heat to keep a special calf barn warm, and the larger animals will contribute to the warmth. On larger farms, the calf barns are usually furnished with artificial heat. After a calf is six weeks to two months old, he can then be transferred to a larger pen, where a number of calves may be put together.

Bedding. Adequate quantities of clean bedding should be furnished. It has been found, however, that the most satisfactory method is not to clean the pens daily, but to let the litter accumulate, adding bedding in such quantities as are needed to keep the pen dry, and removing the litter only when the accumulation is sufficient to permit the calves to jump out of the pen. The accumulated litter generates heat and makes a much warmer bed for the calf than would be possible if it were removed daily. Some of the most successful dairymen let the litter accumulate for weeks and sometimes months before it is removed.

Calf ties. After they have been given their feeding of milk, calves are likely to suck one another. In doing this, they swallow considerable hair,

[1] Roadhouse and Perry. Calif. Agr. Expt. Sta. Circ. 319. 1930.

which, not being digestible, will form hair balls in the abomasum. Frequently, on slaughter or post mortem examinations, from one up to as many as 20 or 30 hair balls may be found in a calf's stomach. They vary in size from minute ones up to balls two or more inches in diameter. To avoid the ingestion of hair, calves should be tied following the feeding for a period of one-half hour or more. The most satisfactory ties are stanchions that occupy a side of the calf pen. Commercial calf pens have many desirable features of convenience, but homemade ones can be built that serve the purpose adequately.

Pasture. As skim milk is largely water, there is no particular advantage of pasture grass over hay for a calf receiving milk. The calf, too, is very susceptible to injury from exposure to the hot sun and flies. Not until the calf is at least four months of age is it advisable to turn him out on pasture, and then only when shade is afforded.

Silage. While there is no evidence that silage is harmful to a calf receiving milk, there is nothing to indicate that it has any particular value. In the main, silage is not so palatable to a young calf as is hay, and for this reason, it is much better that the calf get its roughage in the form of hay rather than silage.

Spring vs. fall calves. From the standpoint of ease of raising the calf, there are advantages for both fall and spring calves. The fall calf must be raised in the barn, and it is more likely to suffer from vitamin deficiency, particularly vitamins A and D, than is the spring calf, as winter milk is normally much lower than spring milk in its content of both these vitamins. The spring calf, however, is more likely to suffer from damage by flies and from digestive disturbances due to bacteria because of the favorable weather conditions for bacterial development. From the standpoint of the economy of raising to maturity, the fall calf has considerable advantage over the spring calf. The fall calf is old enough to make good use of pasture by the next spring, and by the time it is two years of age it thus will have had two pasture seasons. The spring calf is too young to make use of pasture the first season and will have had but one pasture season when two years of age. In addition the fall calf will have been on pasture when its food requirements were the highest—from 18 months to 24 months of age—while the spring calf will have spent the period from 12 to 18 months of age on pasture.

Weaning the calf. Unless skim milk is unusually plentiful, there is no advantage in feeding it to a calf more than six months old. At that time the normal calf has reached sufficient development to be able to handle enough grain and hay to continue its normal growth. The change from milk to a hay and grain ration only should be made gradually. First the feeding of milk should be limited to once a day, and then the amount of milk should be reduced daily until in ten days it is completely eliminated. At this point if nonlegume hays and low protein concentrates have been fed, it is necessary to add some high protein concentrates to the ration, or to change from a grass hay to a legume hay. One of the most common mistakes made in weaning a calf from skim milk is failure to

furnish adequate protein in the ration. If legume hays are fed, then any ordinary grain mixture will suffice. If nonlegume hays are fed, a concentrate mixture containing at least 40 per cent of high protein concentrate, as linseed oil meal or cottonseed meal, is needed to supply the necessary protein requirements. In this case, two pounds of the concentrate should be fed daily.

Production of veal. Vealers consist of a group of immature milk-fed bovine animals usually not over 3 months of age.[1] There are three classes: light weights of 110 pounds or less, medium weights of 110 to 180 pounds, and heavy weights of 180 pounds or more. Each one of these classes is divided into five grades on the basis of quality. One of the requisites of veal is that the flesh must be nearly white in color. To produce veal of this color it is essential that no hay or grain be fed; only milk will maintain the desired color.

Feeding for veal production. Nothing but whole milk will produce veal of the highest quality. Numerous trials have shown that it requires about ten pounds of milk to produce one pound of gain. Since the object is to produce as rapid gains as possible, it is necessary to feed the calf as much milk as it will consume. The most satisfactory way is to permit the calf to nurse the dam or some nurse cow. Apparently a calf can consume considerably more milk when it takes the milk directly from the dam than when it is hand fed, without suffering digestive disturbances. While digestive disturbances resulting in scours are detrimental to calves that are to be raised to maturity, they are even more so to the veal calf. The set-backs occasioned from scours will not permit any profit in the production of veal.

Economy of veal production. As veal can be produced only on whole milk, there are definite limitations to the advisability of the production of veal. Ten pounds of milk are required on the average to produce one pound of gain; if milk is worth $2.00 a hundred, each pound of gain costs 20 cents. Profits made on the production of veal, if there are any, must be from the initial weight of the calf. The birth weight of the calf is therefore a most important consideration. The most desirable weight of a veal calf is 150 pounds. The following table shows the amount of milk that is required to raise calves of various birth weights to 150 pounds and the value of the milk consumed when $2.00 per hundredweight. A calf weighing 40 pounds at birth will require 1,100 pounds of milk by the time it has reached 150 pounds in weight. With milk at $2.00 per hundredweight the cost of the milk is $22.00. With veal at 10 cents per pound the carcass is worth but $15.00. On the other hand, a calf weighing 100 pounds at birth requires but 500 pounds of milk to bring it to the 150 pound weight. The milk there will have cost but $10.00. Heavier calves will require proportionately less milk. Unless the calves are of large sizes to begin with and the milk of low cost or the veal of high value, there is little profit to be made in the production of veal.

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[1] SLATER. U. S. Dept. Agr. Circ. 28. 1928.

Amounts of Milk Required to Bring Calves of Various Birth Weights up to 150 Lbs.

Birth Weight	Amount of Milk	Value of Milk at \$2.00 per Cwt.	Value of Veal at 10 Cts.
40	1,100	\$22.00	\$15.00
60	900	18.00	15.00
80	700	14.00	15.00
90	600	12.00	15.00
100	500	10.00	15.00

CALF DISEASES

Since diseases exact a large toll from dairy herds, one of the first considerations in maintaining a healthy, profitable herd is to select animals that are free from disease. The second problem is to take the proper precaution to prevent diseases, and the third is the care and treatment of animals that have become infected.

Selecting calves free from disease. In so far as is possible, calves should be selected from cows that are free from diseases which are communicable to the calves. Such diseases as tuberculosis, Bang's disease, and Johne's disease are readily communicable to the calf from the dam, and no calves should be selected from animals infected with these diseases unless the calves are held in isolation for at least 30 days.

Prevention of diseases. In medicine it is universally recognized that the best treatment for diseases is their prevention. In the raising of calves there are a number of things that may be done to insure a minimum of diseases. These factors are discussed in Chapter 38. Even with reasonable attempts to prevent diseases most herds will experience some infection among the calves, since calves are much more susceptible to disease than older animals. In addition to the majority of the diseases to which older animals are susceptible, there are a number of diseases that are limited to calves. It is only those diseases with which calves are afflicted, and not those afflicting older animals, that will be discussed at this point, together with the methods of prevention and the remedy.

Common scours. Common scours is the most common ailment of calves. The majority of calves are afflicted with this disease at some time during their lives. The injury done by common scours is impossible to measure. Very seldom does the disease itself end fatally, but it reduces the vitality of the calf to such an extent that susceptibility to other diseases is greatly increased. In addition to this, common scours cause a setback to the calf from which complete recovery is not always effected. Common scours attacks calves at any age. However, calves that did not get colostrum milk are more susceptible at all ages than are those that secured colostrum.

Symptoms. The first symptoms of common scours are general listlessness, dull appearance of the eye, a drooping of the ears, usually increased

respiration, and sometimes increased temperature. These are followed by diarrhea.

Causes. Overfeeding is probably the more frequent causative factor. Sheehy, who has given much attention to this problem, finds that when a calf is overfed, large curds are formed in the stomach that are not completely digested before the next feeding. These curds, therefore, become the subject of putrefactive changes, which, in turn, cause the diarrhea. Too cold milk, also, may initiate digestive disturbances. Probably next to overfeeding is general uncleanliness and contamination of pails, pens, and other equipment with which the calf may come in contact. Alfalfa hay also may sometimes cause looseness of the bowels which is sometimes mistaken for scours.

Treatment. As common scours is due to abnormal conditions of the digestive tract, the first requisite in treatment is to reduce the feed to one-half or less of the normal and to continue the reduced ration until complete recovery is effected. Sheehy also advises diluting the milk with water. A number of other treatments are recommended. A castor oil drench of 3 ounces of castor oil to a pint of milk is recommended by some. This should be administered before any other treatment is given. A number of persons have found that one teaspoonful of formalin given in a pint of milk for two or three consecutive days is effective. Eggs also are often effective in checking the progress of this disease. One or two eggs in a pint of milk should be given at each feed. Various sulpha drugs are now used with good success in the treatment of scours. Sulphanilamide should be given at the rate of one grain per pound of live weight. Next in importance to reducing the feed and administering some therapeutic measure is keeping the calf warm and dry. While common scours is not contagious, it is well to remove affected calves from the healthy ones.

Acute infectious scours. One of the major causes for heavy losses among calves during the first week or ten days of life is acute infectious scours.

Symptoms. Acute infectious scours may be differentiated from the common scours by the more rapid onset, sudden prostration, and extreme weakness. The body temperature is usually greatly elevated and appetite is lacking. The bowel discharges are abnormal. In most cases the feces are yellowish-white and very offensive of odor. In other cases they are bloody, due to damage to the gut wall which causes hemorrhage into its contents. The animal rapidly becomes dehydrated because of the large amounts of fluid discharged into the gut contents. This results in sunken eyes and retracted belly. The respiration is short and rapid and with the progress of the disease the temperature drops. Death ensues as a rule in 24 to 48 hours.

Causes. The organisms responsible for this disease are not well known. For calves that do not receive colostrum, apparently common coliform organisms produce the above symptoms. Infectious scours often attacks calves that receive colostrum and in severe outbreaks attack nearly all calves in a herd even though they have received colostrum. One type apparently gains entrance through the navel cord, since the first evidence

is a swelling in the region of the navel. For many cases the causative organism is obscure and all that can be said at the present is that the disease is due to some highly infectious organism.

Prevention. The solution of the infectious scours problem lies in prevention, because once a calf is attacked treatments now known are not very effective. The first and most important factor in its control is proper sanitation. Sick calves must be removed from the healthy ones and the premises thoroughly cleaned and disinfected. The stall in which the cow calves must be cleaned and disinfected. During the summer a clean, grass-covered lot is an excellent place for calving. The calf should receive colostrum for the first day or two, preferably by nursing its dam, and left in an isolated pasture for ten days before being returned to a barn in which there has been infection. Care should be exercised in feeding, as there is some evidence that common scours predispose the calf to attacks of the infectious variety. Dipping the navel cord in tincture of iodine or a 10 per cent solution of silver nitrate immediately after birth is effective in preventing infection from this source.

Treatment. In most case the onset and progress of the disease is so rapid that treatment is of little avail. Administration of four to six ounces of castor oil followed by a standard dose of sulphaguanidine, sulphathalidine, sulphadiazine or sulphamerazine has proven helpful. Intravenous administration of salt solution and glucose is helpful in overcoming the dehydration and furnishing energy.

The administration of antiserums, at one time recommended, has been found wanting. It is possible that future research will develop effective antiserums, since toxic production of the causative organisms seems to be an important factor in producing the symptoms observed.

Pneumonia. Bronchial pneumonia or common pneumonia usually occurs when the calf is in a weakened condition, resulting from scours or some other disease. Common pneumonia is probably the specific cause of most deaths among calves.

Symptoms. The temperature increases to 104° or 106° F. This is followed by a cough, and the respiration becomes increasingly rapid with the advance of the disease until there is "gasping" for breath. The skin, particularly at the nose, becomes dry. In addition, loss of appetite, general listlessness, and weakness occur. A calf that recovers from pneumonia is left in a weakened condition and will seldom attain the vigor that it would have had if it had not been so infected.

Causes. The most common cause of pneumonia is exposure to drafts and damp, wet quarters. Of course, a predisposing factor, as has been previously mentioned, is a weakened condition of the calf from some other disease.

There is also a highly infectious type of pneumonia that will attack calves even in the most healthy and vigorous state. One form is probably due to a virus, with other bacteria as secondary invaders.

Treatment. Warm, dry quarters is the most important factor in the treatment of this disease. A mild purgative, such as castor oil, should be administered as in the case of common scours; three ounces of castor oil

should be given in one pint of milk. The appetite of the calf declines to such an extent that there is no danger of overfeeding.

Goiter. In certain sections of the United States goiter is a common affliction of calves, and the losses caused thereby are heavy.

Symptoms. The chief characteristic of goiter is a swelling of the thyroid gland, located in the throat just below the jaw. There are various degrees of swelling, from one of moderate size to one that is of such size that the calf is choked.

Cause. Goiter in calves is caused by insufficient iodine in the ration of the dam during pregnancy. In many sections there is insufficient iodine in the soil. As a result, plants grown on such soil are deficient in iodine.

Treatment. The calf affected with goiter should be given a small amount of iodine in the milk, but the best way of treating goiter is to prevent its onset by supplying iodine in the ration of the pregnant cow. Under ordinary conditions, the iodized salt on the market furnishes an adequate amount of iodine for the prevention of goiter. If iodized salt is not fed and goiter is encountered, one tablespoonful of potassium iodine solution should be fed daily to pregnant cows. The iodine solution is made up by adding one teaspoonful of potassium iodide or sodium iodide to one gallon of water. One grain of potastium iodide daily is adequate. It may also be furnished in the form of tablets which may be dissolved in drinking water.

Ringworm. Calves are very susceptible to ringworm, and it is not uncommon to see whole calf herds so affected.

Symptoms. Ringworm causes the hair to fall out in spots of various sizes. It may attack any part of the body but is more frequently found first around the neck, head, and shoulders. Ringworm is very irritating, and the calf constantly wants to rub the affected parts against fences or walls of the pen. The disease usually disappears during the summer when the calves are on pasture.

Causes. Ringworm is caused by a fungus which attacks the epidermic layers of the skin. The disease is very contagious, its spread being effected by direct contact with an infected animal or from objects that have been contaminated by the infected animals.

Treatment. First the infected spots should be washed with soap and water and the crusts removed, and then tincture of iodine or nitrate of mercury ointment should be applied daily until cure is effected. All pens should be thoroughly disinfected with ordinary disinfectants, and the fences or pen walls should be whitewashed, to destroy the spores scattered by the infected animal. Also, the infected animals should be removed from the noninfected ones to prevent the further spread of infection.

It has recently been shown that a solution of Phemoral (1:1000) when properly applied to the ringworm scabs is very effective. The Phemoral is applied by a wad of cotton soaked in the solution and should be administered three times at weekly intervals.

Warts. Warts may affect calves on any part of the body, but they appear most frequently about the eyes, the neck, and shoulders. They cause no particular damage but are unsightly. There are two types of

warts: one that forms a cauliflower-like tumor, and one that forms a dense clublike growth. It is the latter that is the more common and unsightly. Warts range in size up to a weight of 14 pounds.

Cause. Warts are caused by a filterable virus.

Treatment. The most satisfactory way of treating warts is by surgery. They may be twisted off if small, clipped off with a pair of scissors, or ligated by means of a rubber band or a horse hair tied tightly around the base of the wart. The latter strangulates them and they will ultimately slough off. After removal, the roots should be cauterized with a caustic or glacial acetic acid.

Chapter 30

RAISING THE HEIFER FROM WEANING TO CALVING TIME

Importance of rapid development. As a heifer following weaning is comparatively easy to raise, this particular period in the animal's life is given less attention than any other period. There are, however, some very important economic problems to consider in feeding and caring for heifers of this age. The important fact to keep in mind is that a maximum development and earliest maturity consistent with cost is to be desired. It has been shown previously that earliness of maturity is, to a considerable extent, dependent upon the rate of growth. The nutrient requirements for maintenance are proportional to the weight of the animal. Assuming a constant rate of growth up to 1,000 pounds of live weight, when one animal, because of liberal feeding, attained that weight in 600 days while another animal, because of a lower plane of nutrition, required 900 days, 50 per cent more nutrients was required for the maintenance of the second animal than for the first. As the average weight for the period in either case is 550 pounds, if the calf weighs 100 pounds at the beginning, 550 pounds of live weight must be maintained for 300 days longer in the case of poor feeding than in the case of liberal feeding. The maintenance requirement for this weight is approximately four pounds of total digestible nutrients per day. The slower grown heifer would, therefore, require 1,200 pounds more total digestible nutrients to bring it to the 1,000 pounds live weight than would the more rapidly grown one. Unless the cost of the ration for the slower growth is less than two-thirds of the cost of the faster growing ration, the faster growing ration brings the animal to 1,000 pounds weight at lower cost.

A second point in favor of rapid growth and development is that the earlier maturing heifer will bring earlier returns on the investment. A third point in favor of rapid and full development is the fact that a higher production may be expected from the well-developed heifer at the time of the first calving.

Feeding the calf from six months to one year. Since the calf is weaned at six months, this is a critical period in its development. Because there is reduced food intake, the change from skim milk to a dry feed usually checks growth temporarily. At this point the amount of grain allowed should be increased, and particular attention should be paid to the protein content of the ration. A normal Holstein weighs approximately 400 pounds at weaning time. According to Morrison's Feeding standard, such an animal requires .8 to .9 pound of protein and 6.5 to 6.6 pounds of total digestible nutrients daily. If the animal is furnished a low protein roughage ration, there is a great shortage in protein unless a high protein concen-

trate is added. An illustration will indicate the importance of sufficient protein in the ration at this time. A 400 pound calf will consume approximately ten pounds of hay daily. Ten pounds of timothy hay contains .29 pound of protein, which is .6 of a pound short of the requirement. It would require two pounds of linseed oil meal a day to supply the additional protein requirement. Ten pounds of alfalfa, on the other hand, contains more than enough protein for normal growth, and the concentrate that is added may be of any kind. More frequently than not, heifers at this age are suffering from insufficient protein in the ration.

Roughage. From the previous discussion it is apparent that a legume hay is the best roughage for the heifer from six months to one year of age. This can be fed *ad libitum*, and if it is of good quality, the animal may take more than 2½ pounds per 100 pounds of live weight. On most farms silage is available, and while there is no particular reason for feeding silage to calves of this age, there is no evidence that it is harmful. If silage is fed, it may replace one-half of the hay ration, three pounds of silage replacing one pound of hay. In so doing, however, if the concentrate is corn or barley or similar low protein grains, there is a danger of getting insufficient protein. If grass hays are fed, such as prairie, timothy, and sudan grass, a high protein concentrate must be furnished.

Hay alone. Roughage has been tried in numerous experiments for calves of this age,[1] and all have resulted in failure to secure normal growth. The reason is probably that the rumen of calves is relatively small up to approximately one year of age, and the calf is, therefore, unable to consume enough feed.

Concentrates. The heifer at this age should have at least two pounds of concentrates daily if the roughage is of high quality, and more grain if it is of low quality. If the roughage is a legume, any kind of grain will suffice. Corn only, corn and barley, and barley only have been used in different trials with excellent success. In most cases, however, the regular herd ration is satisfactory. When the roughage is of the low protein variety, the grain mixture must have at least 25 per cent of digestible protein. If the roughage consists of a mixture of one-half legume and the other half nonlegume, a grain mixture of two parts oats, one part barley, and one part corn, furnishes adequate protein.

Pasture. Pasture grass, when immature, has adequate protein content to supply the needs of calves from six months to a year of age. However, it is still too bulky to produce normal growth in heifers of this age, and a concentrate should be added; this should be the same as when alfalfa hay is fed. If the grasses are mature, the protein content becomes inadequate, and the grain supplement should be changed to approximately that recommended for the grass hays.

Minerals. When the calf receives skim milk, adequate phosphorus and calcium for normal growth are supplied. When legume roughages are fed, the calcium supply is adequate, but under certain soil conditions

[1] Reed, Fitch, and Cave. Kans. Agr. Expt. Sta. Bul. 233. 1924.
Woll. Jour. Dairy Sci. 1:447–461. 1918.

there may be a deficiency of phosphorus. When the grass hays are fed, there may be a deficiency of calcium. It is, therefore, to be advised that bone meal be supplied to calves on such rations. If it is not needed, there is enough experimental evidence to show that an excess will do no harm, and the costs are negligible. Ordinary salt should always be available. Often calves, especially when on pasture, are forgotten and not supplied with salt.

Raising yearling heifers. The age from one year to just before calving is probably the easiest time to care for and feed dairy cattle. The digestive tract of the year old heifer has assumed mature proportions and she can handle any feed in the same proportion that the mature animal can. The care of heifers naturally divides itself into two sets of problems: first, those concerned with winter feeding; and second, those concerned with summer feeding.

Winter feeding. The different problems of winter feeding center around the kind of roughage used. For normal growth a yearling heifer needs an equivalent of 1.2 per cent of its body weight in total digestible nutrients and from .1 to .13 per cent in digestible protein. The kind and amount of concentrate supplement to be fed depends upon the kind and quality of roughage supplied.

1. If legume roughages are of excellent quality and early cut, and the heifer consumes two and one-half to three pounds per 100 pounds of live weight, satisfactory growth can be secured on roughage alone. If, however, the roughage is unpalatable, so that an insufficient nutrient intake results, corn is an adequate supplement. Any other grain cheaper than corn may be substituted.
2. When legume hay and low protein hays mixed are fed, if these hays are palatable and consumed at the rate of two and one-half to three pounds per 100 pounds of live weight, normal growth is secured. This type of roughage, however, is seldom palatable enough for the heifer to consume the requisite amounts. Usually it is necessary to furnish one to two pounds of concentrate daily in order to secure normal growth on this type of roughage. One-third of the concentrate should be of the high protein type.
3. When legume hay and corn silage are fed as roughage in the proportion of one part hay to three parts silage, the situation is identical to that with mixed hay as the only roughage.
4. Corn or sorghum silage as the only source of roughage makes it necessary to furnish both additional energy and protein in the form of concentrate supplement. Silage is too bulky for the normal heifer to consume enough to furnish the necessary energy. Nonlegume silage is also greatly deficient in protein. At least two to three pounds of concentrates must be fed daily; one-half of these should be of the high protein group, such as linseed oil meal, cottonseed meal, soybean meal, or gluten meal.
5. When the roughage consists of the low protein kinds, such as timothy or prairie hay, corn, or any sorghum fodder, high protein concentrates

must be added. Satisfactory growth has been secured when silage was consumed at the rate of three pounds per 100 pounds of live weight plus two to two and one-half pounds of either linseed oil meal, cottonseed meal, or gluten meal. Five pounds of bran proved too bulky as a supplement to corn silage.

Whether roughages of the high protein types are adequate without concentrate supplements depends upon the quality and palatability of the hays and the condition of the heifers. Early cut, leafy, and well-cured roughages are usually palatable enough that the heifer takes in adequate nutrients. When good roughage at moderate costs is available and concentrates are high priced, it is probably better to feed roughage alone even at the expense of a slightly reduced rate of growth.

Concentrates alone. Concentrates may be the sole source of nutrients for growing heifers if vitamins A and D and calcium are supplements. Vitamins A and D may be furnished in cod-liver oil, and calcium in the form of calcium carbonate. Unless these supplements are furnished with the grain, serious difficulties are encountered that usually terminate fatally. Feeders of baby beefs encounter these difficulties where grain is offered freely. Frequently when calves have free access to grain they do not eat hay, and hay is the chief source of calcium and vitamins A and D.

Summer feeding. Good pasture furnishes adequate nutrients for the growth of yearling heifers. Unless there is a shortage of pasture, it does not pay to feed concentrates to heifers on pasture. When heifers in ordinary condition are let on pasture they continue to gain at normal or above normal rates. When heifers in poor condition are let on pasture they will gain at faster than normal rates. Heifers that are somewhat below normal, when let out on pasture, frequently have caught up to normal by the end of the pasture season. Those that are much below normal, however, will not make sufficient gains on pasture to make up for the deficiency. Animals that are extremely fat when put on pasture do not as a rule make normal gains.

Housing for yearling heifers. The type of housing that will furnish adequate protection for yearling heifers differs with the severity of the climate. It is not necessary to furnish as warm quarters for heifers as for the milking cows. Many believe that all the protection necessary for heifers is a roof with sides that will "break" the wind, even in severe Northern winters. But if the heifers are subjected to severe cold, much more feed is needed to supply the energy for additional production of heat, and this additional energy must come from added concentrates; therefore this type of protection becomes economically unsound under most conditions.

In the colder climates, if the cow barn has enough room, a large pen in a corner of the barn in which the heifers may run loose is very satisfactory. From 35 to 45 square feet should be allowed per head. Many find it advantageous not to clean out the pen for weeks at a time but to keep the pen dry by the daily addition of bedding. If the cow barn does not permit the building of this pen, a cheaply constructed shed built

with matched boards is adequate. Here, too, the heifers may run loose and the litter may accumulate to form a warm bed. Under this plan there is no need for concrete or other types of floors. The dirt serves as a good drain for excess liquid. The only inside equipment needed is a hayrack with a manger and a watering trough.

For warmer climates, a satisfactory shelter is a partially open shed. This should be closed on all but part of the south side.

When stalls and stanchions are available in the regular barn, the heifers may be quartered there. Some difficulty, however, will be experienced in keeping them clean.

Age at which to breed heifers. The age at which heifers should be bred depends to a certain extent upon the stage of development, which varies with the breed and individual animal. It has been pointed out previously that growth is retarded by lactation, if not entirely checked. The following may be taken as the age to breed normally developed animals of the different breeds:

Brown Swiss	21 months
Holsteins	18 months
Ayrshires	17 months
Guernseys	16 months
Jerseys	15 months

Heifers that are larger than normal for the age may be bred earlier. Those that are smaller should be bred correspondingly later.

Gestation period. The average gestation period for the cow is 280 days, with a variation from 265 to 295 days. Wing reports an almost equal number of births for each day from the 274th to the 287th day. Although some claim a slightly longer gestation for male calves than for females, Wing found no difference.

Cost of raising heifers. The cost of raising dairy heifers varies greatly, depending upon the price of feeds and the methods of raising. Feed makes up more than one-half of the cost. Some other items are the expenses of labor, housing, bedding, and veterinary service. To this must also be added the initial value of the calf.

While the amount of feed required to raise a calf to two years of age varies with the size of the animal and the method of raising, these variations are not as great as the variations in cost. The first table on page 311 gives the average amounts of feed and labor used in the raising of 889 heifers to two years of age. The next table compares the relative amounts of feed and labor used by Holsteins and Jerseys.[1] These figures are not to be taken as absolute values but as guides in considering the cost of raising dairy heifers. By using the prevailing prices for the various feeds the feed cost can easily be calculated. For most sections it is found that when all

[1] HENDERSON, BOWLING, AND HERRMANN. W. Va. Agr. Expt. Sta. Bul. 277. 1936. HAYDEN. Ohio Agr. Expt. Sta. Bul. 289.

THE AVERAGE AMOUNT OF FEED, PASTURE, AND LABOR REQUIRED TO RAISE 889 DAIRY HEIFERS TO 2 YEARS OF AGE

Whole milk	826 pounds
Skim milk	1,323 pounds
Concentrates	643 pounds
Hay	2,125 pounds
Silage	1,848 pounds
Fodder	217 pounds
Straw	16 pounds
Pasture	332 days
Labor	65 hours

COMPARATIVE AMOUNTS OF FEED, PASTURE, AND LABOR USED IN RAISING HOLSTEIN AND JERSEY HEIFERS TO 2 YEARS OF AGE

	Jersey		Holstein	
	Purebred	Grade	Purebred	Grade
Whole milk (lbs.)	932	794	1,976	596
Skim milk (lbs.)	1,384	1,382	634	871
Grain (lbs.)	900	527	736	585
Hay (lbs.)	2,055	2,120	1,866	1,767
Silage (lbs.)	1,621	2,004	3,142	2,153
Fodder (lbs.)	44	86		178
Pasture (days)	310	335	325	348
Labor (hours)	73	69	55	51

the costs are considered, grade dairy heifers sell for less than the cost of raising.

Feed before calving. Eckles and others have shown conclusively that the level of milk production following calving is dependent upon the condition of the cow at calving time.[1] Beginning about three months before calving time, the heifer should have additional concentrates in order to put on more flesh. The main objective is to put on fat; in order to do this, a mixture of one part corn, one part barley, and two parts oats forms a very satisfactory grain mixture. This should be allowed at the rate of five or six pounds daily if the animal was in medium condition to begin with. The amounts to be fed should be governed more by the condition of the animal than by any arbitrary rules.

[1] ECKLES. Mo. Agr. Expt. Sta. Bul. 158. 1918.

Chapter 31

THE COW'S UDDER—ITS STRUCTURE AND DEVELOPMENT

MILK IS SYNTHESIZED AND SECRETED BY THE MAMMARY GLANDS. ALL members of the class *mammalia* normally possess mammary glands. In the males the mammary glands are rudimentary and inactive except in rare cases. In the female these glands develop to secrete milk following parturition. The dairy cow has been bred and selected for large milk producing capacity for a comparatively long time; this has resulted in the largest mammary development of any species. Students of dairying are therefore naturally interested in the development and structure of the mammary glands of the cow.

The development of the mammary gland from the early embryological stages up to maturity has been carefully studied by a number of people. The more important phases of this development will be discussed after the gross and microscopic anatomy of the developed and functioning gland has been considered.

Evolution of the mammary gland. The development of the mammary gland from the elementary form to the highly specialized form in the dairy cow can be traced up through a number of species.[1] The lowest form of mammalia is represented by some egg laying species found in Australia, of which the duckbill is typical. The mammary glands of the duckbill consist of from 100 to 200 lobules on each side of the median line of the abdominal wall. Each lobule opens to the exterior through a duct like a sweat pore. At the opening of each duct there is a hair and no nipple; the milk oozes out of the ducts to form drops on the hair, and the young lick the drops from the hair.

The next step in the evolution of the mammary glands is the bringing together of a number of ducts into a teat or nipple. This is represented by a group of animals known as marsupials, whose mammary apparatus is enclosed by a pouch, called marsupian, into which the young are placed. The kangaroo and opossum are typical representatives of this group. While from ten to twenty ducts come together in a single teat, there is no milk cistern; each duct comes to an opening in the end of the teat.

Further development in the evolution of the mammary gland is effected by the formation of a milk cistern into which the ducts empty, one teat draining but one or a few of such cisterns. Another marked feature in the evolution of the mammary glands is the crowding together of the several glands into one unit; this, the highest development, has been reached by the cow.

[1] BRESSLAU, E. *The Mammary Apparatus of the Mammalia.* Methuen and Co., London. 1920.

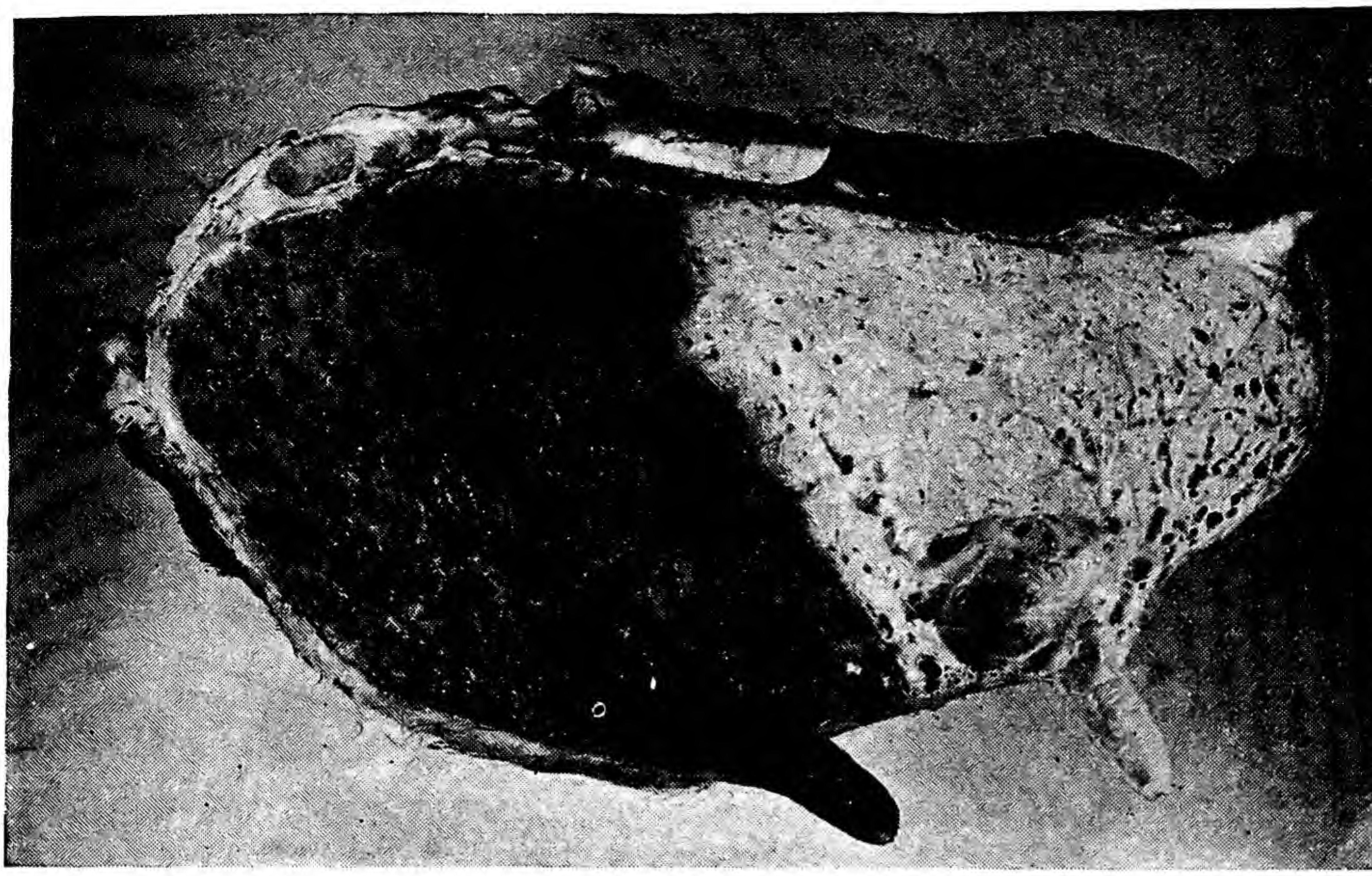


Fig. 66. Longitudinal section of the udder of a lactating cow in which the forequarter was stained with safranin and the rear quarter with methylene blue. Note the sharp line of demarcation between the two quarters, the well defined cisterns, and the porosity of the gland.

The mammary glands of the cow. The mammary glands of the cow are grouped together into one structure, called the udder, which is suspended from the posterior part of the abdomen. The normal udder consists of four glands divided into two halves, with each half again divided into two quarters. The halves are separated by a strong ligament known as the median suspensory ligament. This ligament is also one of the main supports of the udder, the fibers of which, coming out of the abdominal wall, penetrate deeply into the mammary gland. While the fore and rear quarters are not separated by a membrane, they are independent of each other, each quarter having a teat which permits drainage of the milk produced in that quarter. That each quarter is separate in so far as the duct system and drainage is concerned has been demonstrated by the injection of dyes of different colors into the fore and rear quarters. Figure 66 shows the differentiation of front and rear quarters through the injection of methylene blue into the rear quarter and safranin in the fore quarter.

Shape of the udder. There is a great deal of variation in the shapes of the udders of cows. The ideal udder is one that has a level floor upon which the teats are squarely placed and far apart, the forequarters of which extend far forward. Such an udder is deeper in the rear than in the fore, due to the contours of the anatomy from which it is suspended, and, therefore, such an udder is wider in the fore than in the rear. Due to a breaking

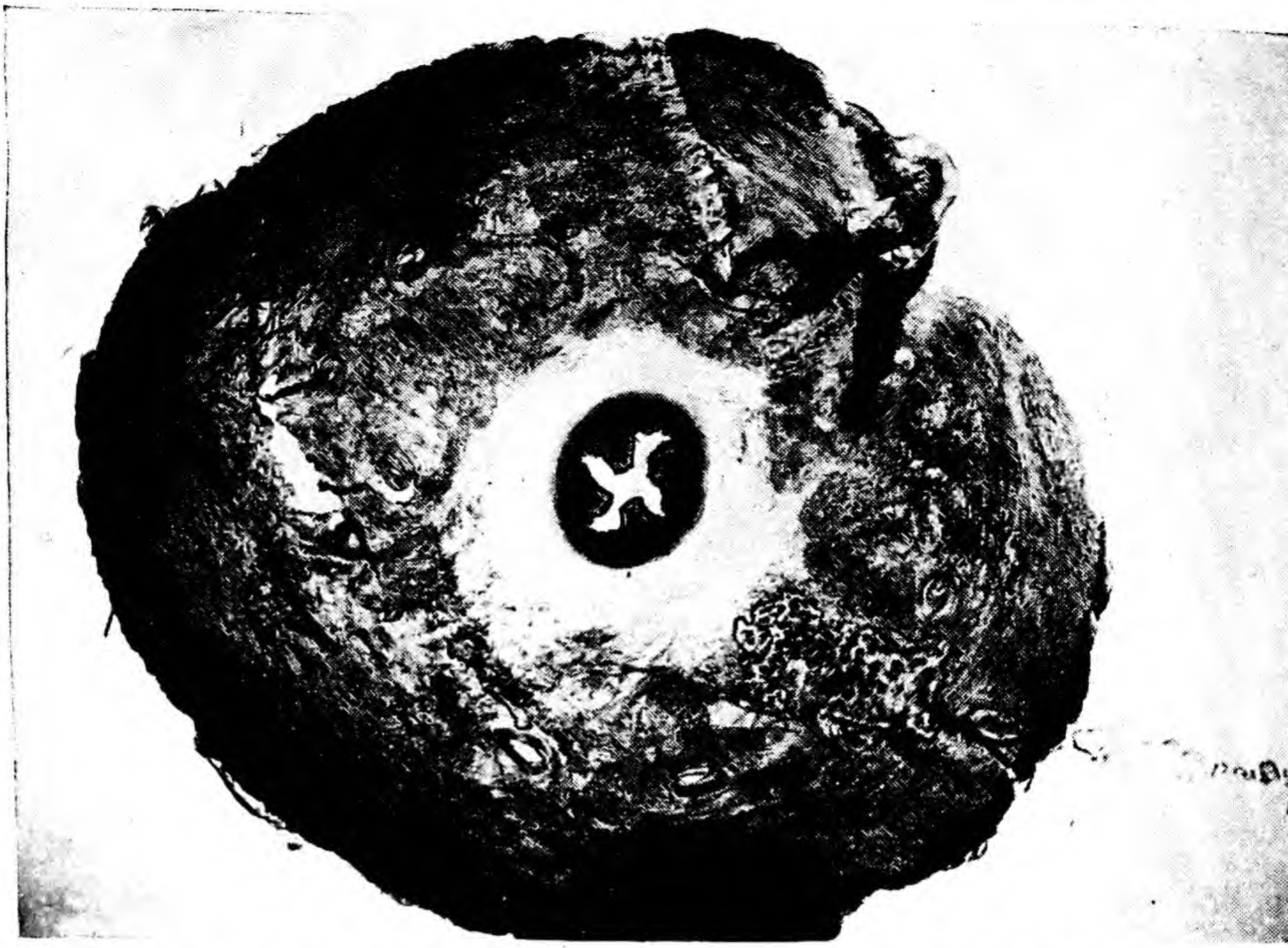


Fig. 67. A cross section of the end of the teat showing the meatus partly open.

of the attachments udders frequently are pendulous. Again, they may be "halved"; that is, the two halves may appear quite separated. Another defect is that of quartering, the quarters appearing to be separated. All these defects are due to some fundamental anatomical factor. The breaking of the udder to form the pendulous type is usually due to a weakening of the lateral and median suspensory ligaments. The halving and quartering are due to an inadequate development of the secretory tissue of each of the four glands. The age of the cow also affects the shape of the udder. With the advance of age udders have a tendency to become more quartered and naturally more pendulous.

Internal structure of the udder. A discussion of the internal structure of the udder is facilitated by considering, one at a time, the number of systems going to make up the anatomy of the udder. These are: the duct system, which permits the drainage of the milk, ending with the teat; the microscopic secreting tissue; the blood or vascular system; the lymph system; and the nerve system.

The duct system. The duct system may be considered by beginning with the teat and following the ramifications back into the udder, ending with the secretory tissue. As previously stated, each of the four glands of the cow's udder has a teat for the exit of the milk. The teat consists of a wall of varying thickness, a teat meatus, and a teat cistern. The teat meatus is the opening in the end of the teat through which the milk is expressed.

This canal is 8 to 12 mm. in length and is lined with a number of longitudinal folds which interrelate so as to close the opening. These folds are kept pressed together by strong sphincter muscles. The general structure of the teat meatus is illustrated in Figure 67. Immediately above the teat meatus begins the teat cistern, which is the cavity of the teat, into which the milk drains naturally. Milk is expressed by shutting off the upper part of the teat cistern and applying pressure below to open the teat meatus. The teat cistern opens up into the gland system. At the junction of these two cisterns there is a circular fold extending into the cavity which makes a sharp line of demarcation between the teat cistern and the gland cistern. It has been reported that in some cases this fold extends into the cavity so far as to hinder the drainage of milk from the gland cistern into the teat cistern.

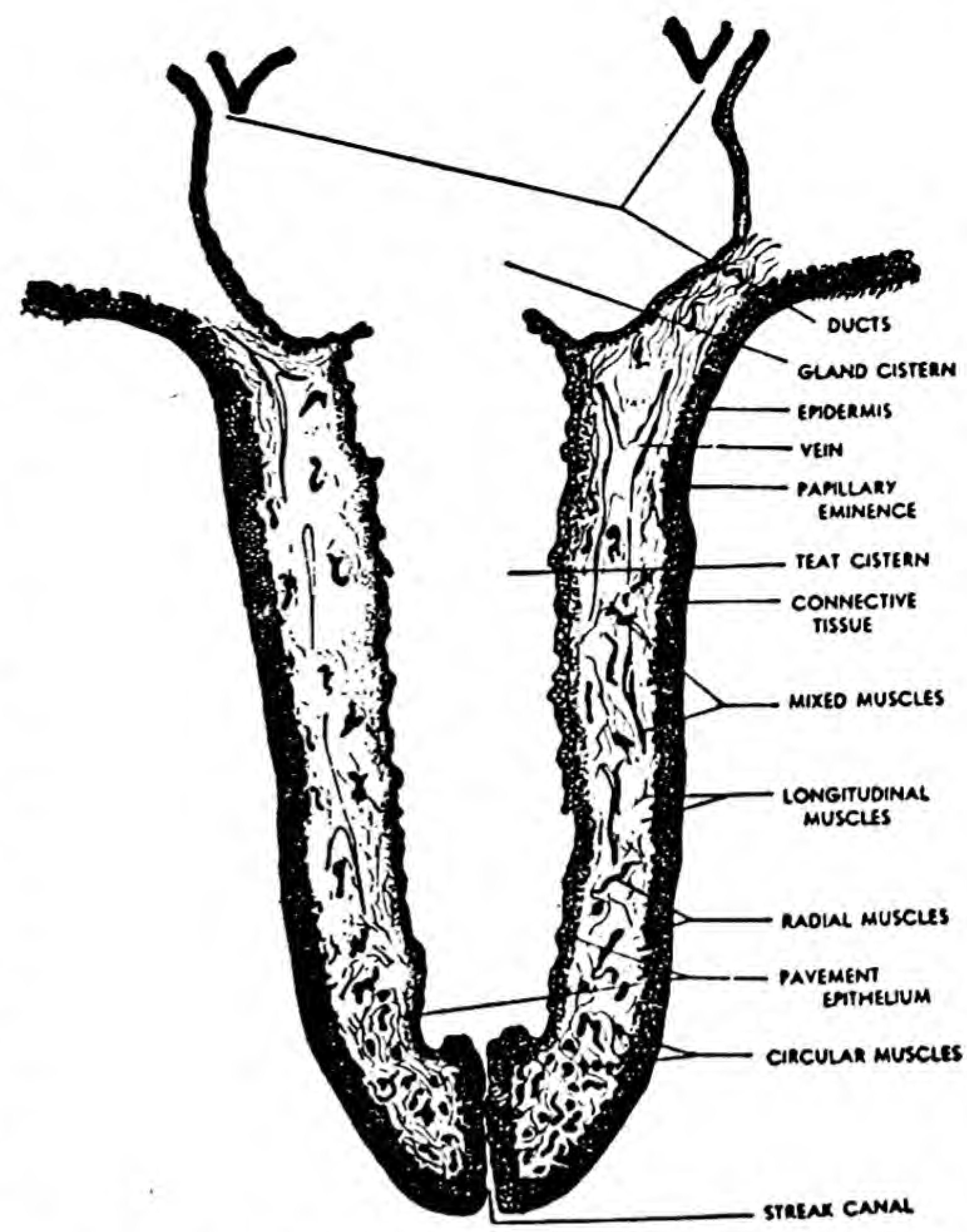


Fig. 68. A longitudinal section of a teat and the lower part of the milk cistern.

A very important practical feature of the upper teat cistern wall is the location of varying numbers of accessory glands that secrete milk. Injury to these occurs often and may result in infection that can readily spread to the rest of the quarter.

Gland cistern. The gland cistern is an irregularly round or oval cavity in the lower part of each gland. It serves as a storage space for milk that drains down from the secreting tissue. The capacity of the gland cistern varies greatly with cows and even with the different quarters in the same cow. A fair average capacity would be about a pint. However, capacities as low as a quarter of a pint have been reported. The milk ducts open in the upper and lateral walls of the gland cistern.

Milk ducts. There are from 12 to 50 or more large ducts in each quarter opening into the gland cistern. Each of these ducts branches and rebranches many times; like the branches of a tree, the final branches end in alveoli which contain the active secreting cells. Each of the large ducts drains a certain portion of the gland, which is called a lobe. Therefore, each gland has as many lobes as there are duct openings in the milk cistern.

The alveolus. The alveolus is a tiny structure resembling a balloon, lined with a single layer of epithelial cells. These cells are nucleated and are the active principals in the secretion of milk. The epithelial cells rest

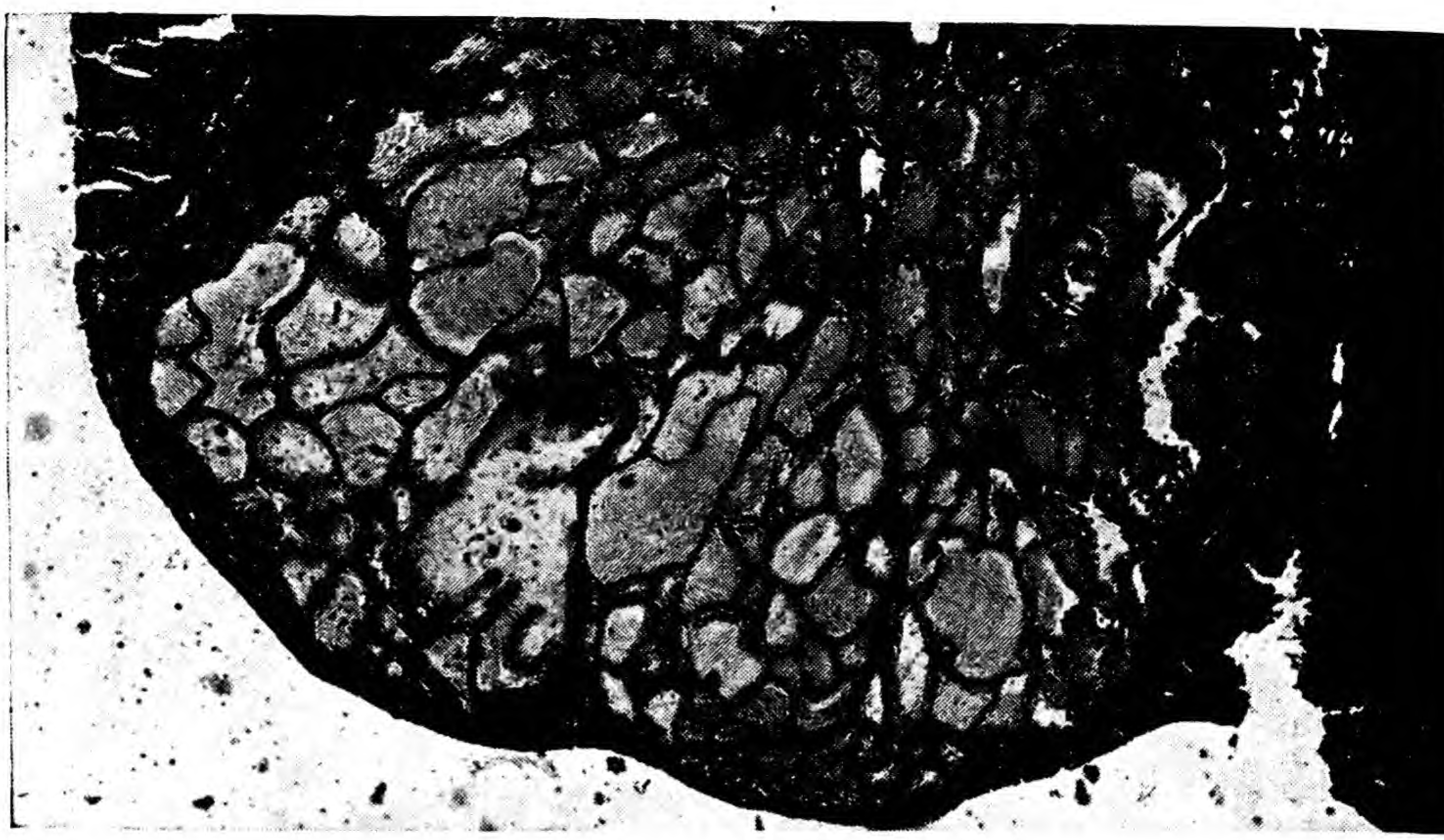


Fig. 69. A microscopic section through a normal accessory gland in the upper teat sinus wall. The alveoli are filled with normal milk.

Fig. 70. Dissection of left side of udder showing main artery branches.

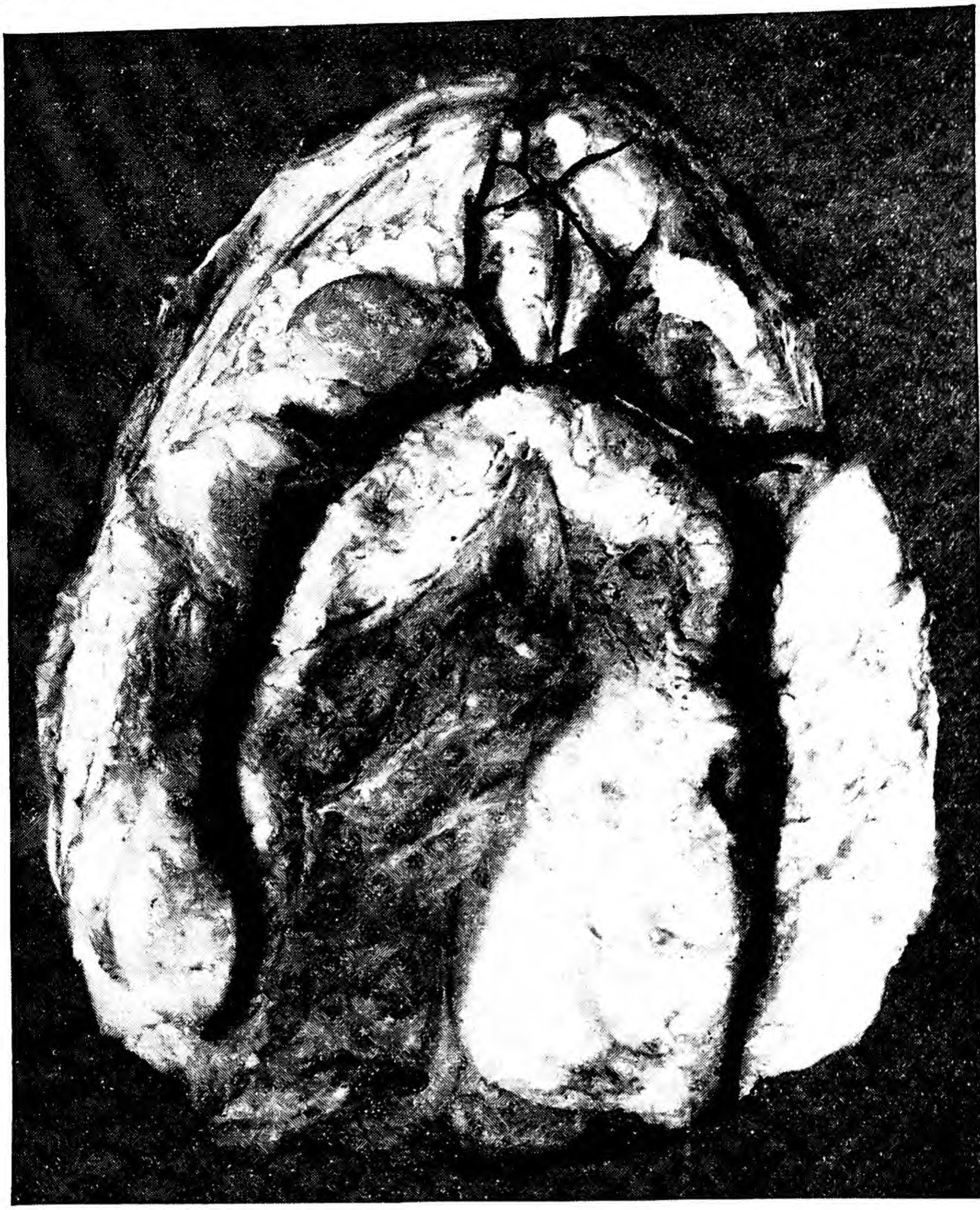


Fig. 71. Dissection showing the veinus ring with anastomatic branches in the posterior. Anteriorly these veins form the "milk veins."

upon a basement membrane on the outside of which are the blood vessels, lymph, and nerve connections. The materials from which milk is made, coming in contact with the base of the epithelial cells through the walls of the tiny capillaries, are picked up by the cells and manufactured into milk, which is expressed into the lumen of the alveolus and then drained out through the duct system. A large number of alveoli drain into a common

Fig. 72. This is a microscopic cross section of an active mammary gland. Note the large alveolar openings and the small cells. The dark spots are fat particles. The inset is a schematic cross section of an alveolus.

ductule forming a small lobule, which is surrounded by a connected tissue membrane. (Fig. 72.)

The circulatory system. The mammary gland gets its blood supply from one artery coming into each half of the udder. This artery, which is known as the external pudic artery and which comes through the inguinal canal, is a branch of the iliac artery. The external pudic artery divides immediately after entering the udder into two main branches—into what is called the cranial and caudal arteries. The forward branch, known as the cranial artery, redivides infinitely to form capillaries supplying the arterial blood for the forequarter, while the caudal branch does likewise to supply the blood for the rear quarter. The skin and the subcutaneous tissue of the udder secure their blood supply from the general peripheral circulation.

Veins. The venous system has its origin with the fine capillaries and, unlike the arterial system, continues to amalgamate with the flow of the venous blood. In the udder the veins all lead together to form what is known as the venous circle—two large veins, one at the base of each half, which are anastomosed (joined together) by a smaller vein in the rear. There are three exits from the venous system of the udder. One runs forward in what is known as the milk vein or subcutaneous abdominal vein; another one, the external pudic vein, parallels the external pudic artery; and a third and smaller one is the perineal, which carries the blood upward, and which enters the body through the pelvic arch. The milk vein

is the one most commonly known; its size has usually been correlated with production. The milk vein may be ligated without affecting milk production; this is easily understood when one knows that there are two other exits for venous blood.

The lymph system. Lymph or tissue fluid has its origin in the blood. It is carried away from the tissue in small vessels known as lymph vessels. In the udder these vessels join together to form larger vessels running toward the posterior dorsal side of each half of the udder, where the supra mammary lymph gland is located. All lymph produced in the udder flows through the supra mammary lymph gland. Three lymph vessels exit from each of the lymph glands to go through the inguinal canal and finally flow back into circulation through the lumbar lymph trunk. The veinlike projections of the udder of many cows are not veins but lymph vessels.

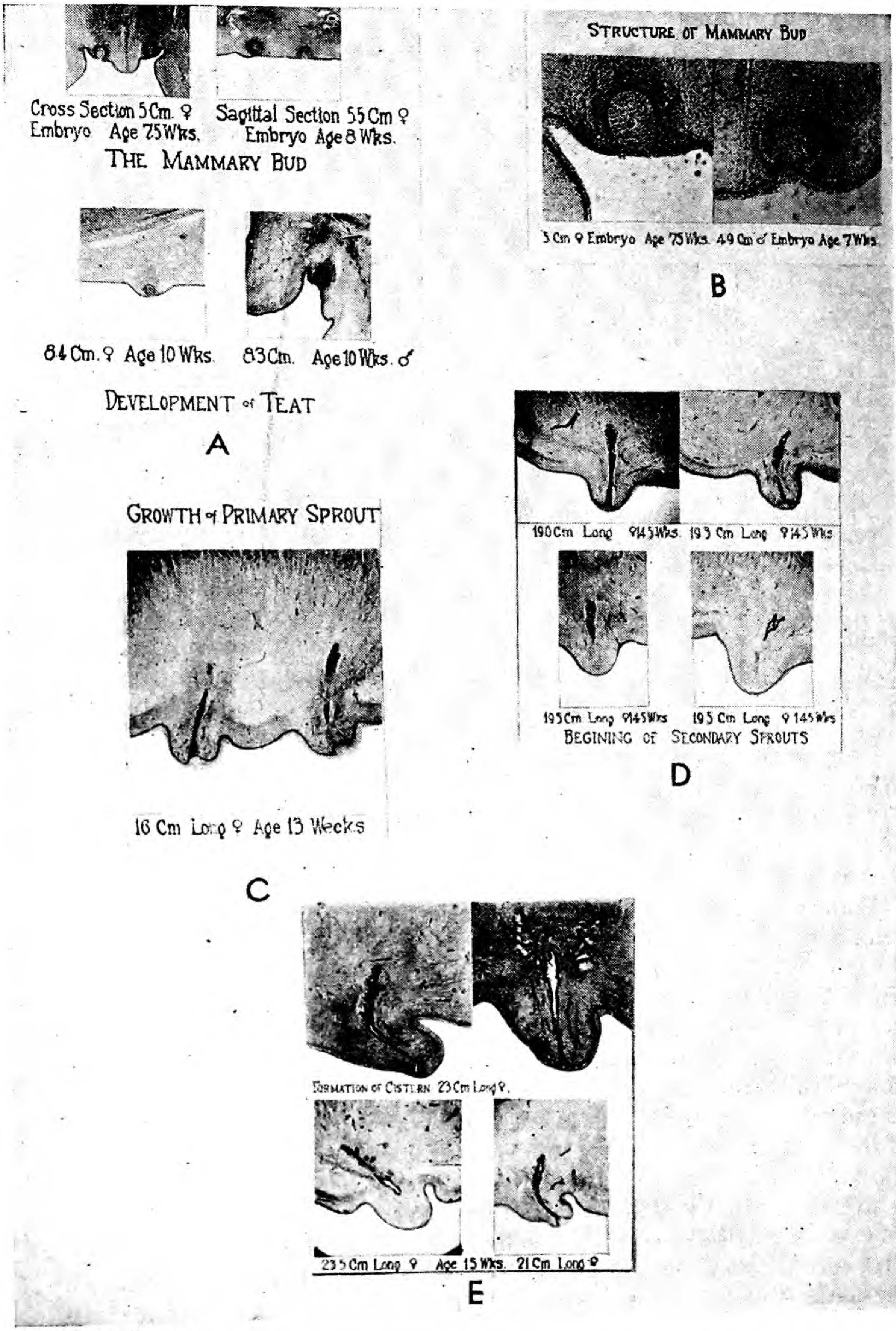
Frequently at the time of calving, lymph is not drained away from the udder as rapidly as it is produced. This is largely responsible for the swelling of the udder commonly experienced following calving. Sometimes the swelling extends along the abdomen as far forward as the forelegs.

The nerve system. The mammary gland is innervated by both spinal and sympathetic nerves. Fibers of both of these systems pass through the inguinal canal to innervate the udder. These branch to follow the arterial system. The spinal nerve may branch before coming through the inguinal canal and send fibers through abdominal foramina anterior to the inguinal canal to innervate the fore udder. The skin and teats of the udder are innervated by lateral branches of the lumbar nerve. A resection of the inguinal nerve does not desensitize the skin and teats.

Cutting the inguinal nerve to the udder has no effect upon milk secretion or the letting-down of the milk. The skin of the teat is innervated by sensory nerves, touch, cold, warmth, and pain perceptors.

Embryological development.[1] The tissue from which the udder develops is differentiated in the very early embryonic development. When the fetus is in the 1.4 to 1.7 cm. stage, there is found in the inguinal region, where the udder later will develop, a thickening of the epithelium on each side of the median abdominal line. This thickened condition gives rise to what is known as the mammary line. The mammary line then starts to differentiate into fore and rear glands, by the formation of what is known as the mammary bud. This is effected by a continued increase in the cells of the mammary line—first to form a hillock, and then a depression into the tissues (see Fig. 73). By continued development of the hillock, there is given rise to what will later be a teat. When the embryo is about 12 cm. long, a core of solid epithelial cells pushes itself inward from the hillock. This core is called the primary sprout, which later canalizes or opens up in the center to form the teat cistern. The primary sprout continues pushing itself into the tissue in a perpendicular way, and canalizes to give rise to the gland cistern. The primary sprout then branches to what is known as the secondary sprouts, each of which gives rise to a duct. When the fetus is about 30 cm. in length, the primary sprout gives rise to a cavity in the

[1] TURNER, C. W. Mo. Agr. Expt. Sta. Res. Buls. 140, 1930, and 160, 1931.



Dr. C. W. Turner

Fig. 73. Embryological development of the mammary gland. *A*, The mammary bud (*top*) and the hillock stage (*below*). *B*, An enlargement of the mammary bud. *C*, Beginning of the primary sprout and development of the teats. *D*, Beginning of the secondary sprouts. *E*, Formation of the cisterns.

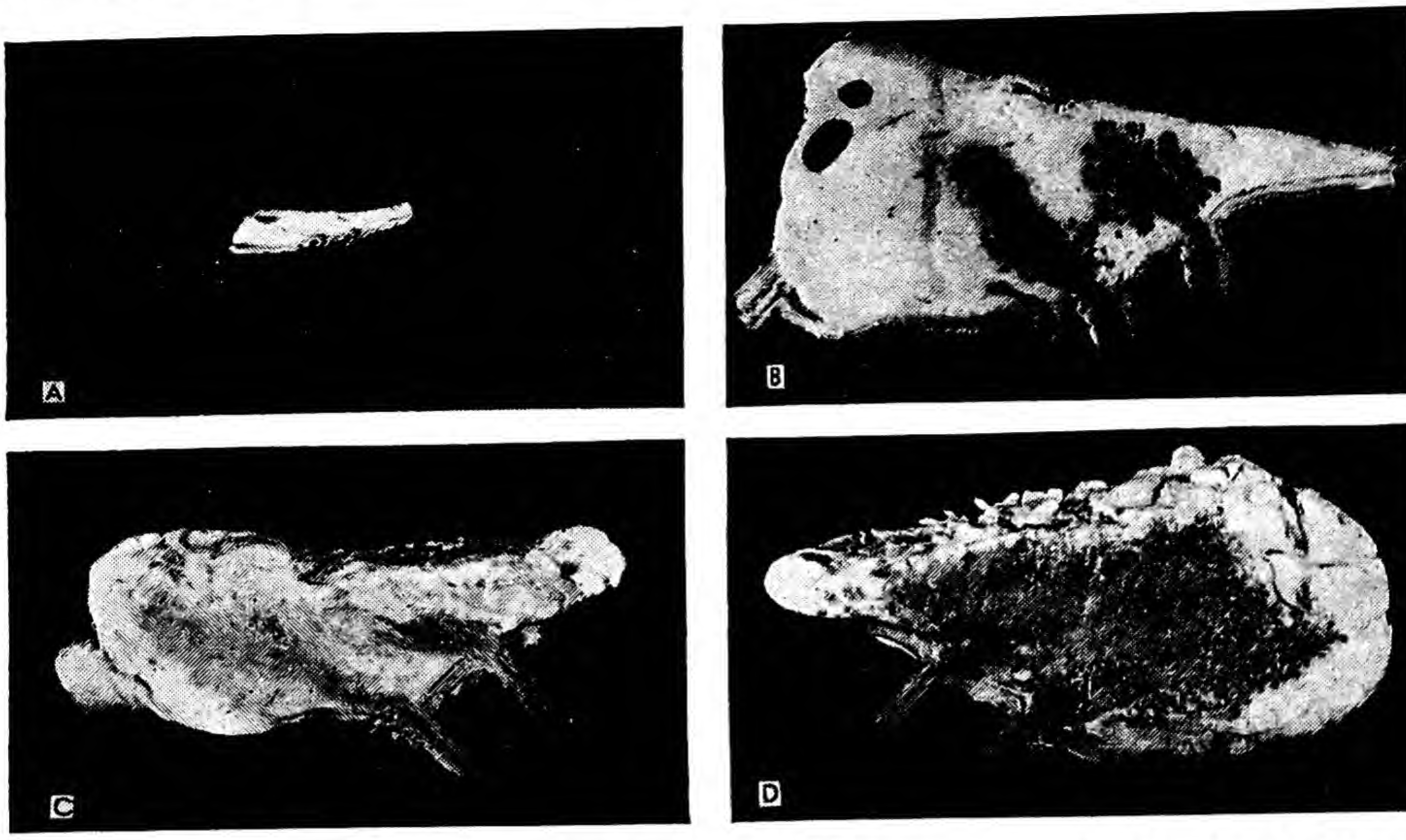


Fig. 74. Four stages in the development of the mammary gland. *A,* Cross section of the gland at birth, showing small milk cisterns and large amounts of fat and connective tissue. *B,* Cross section of the gland of an 11 month old heifer. The ducts have now pushed farther into the fat and connective tissue. The fore and rear quarters are still separate. *C,* Cross section of a two year old virgin heifer, showing more extensive development of the ducts. *D,* Cross section of a three year old virgin heifer. The gland tissue has pushed much farther into the fatty connective tissue, and the fore and rear quarters are now together.

teat, and later on the secondary sprouts canalize to give rise to ducts.

At birth the udder of the female calf has a well-developed cistern of the teat and gland. (Fig. 74.) The secondary sprouts, however, have made only slight development. The udder normally remains stationary until sexual maturity. With each recurring oestrus there is further development of the duct system. The development of the mammary gland from the earliest observed milk line through birth to puberty is illustrated in Figure 74. It is to be noted that for the heifer the major portion of the udder consists of fat, and the development of the duct system, with recurring oestrus cycles, consists of replacing the fatty material with the proliferating ducts.

Pregnancy. Following pregnancy there is a rapid development of the duct system. Most of this development takes place during the first five months of pregnancy, so that at the end of this period the duct system is practically completely developed. With this increase in the duct system there is comparatively little increase in the size of the udder. With the advancing of pregnancy the udder increases greatly in size, due to a different type of development. During the latter part of pregnancy the development is in the formation of the alveoli with their epithelian cells.

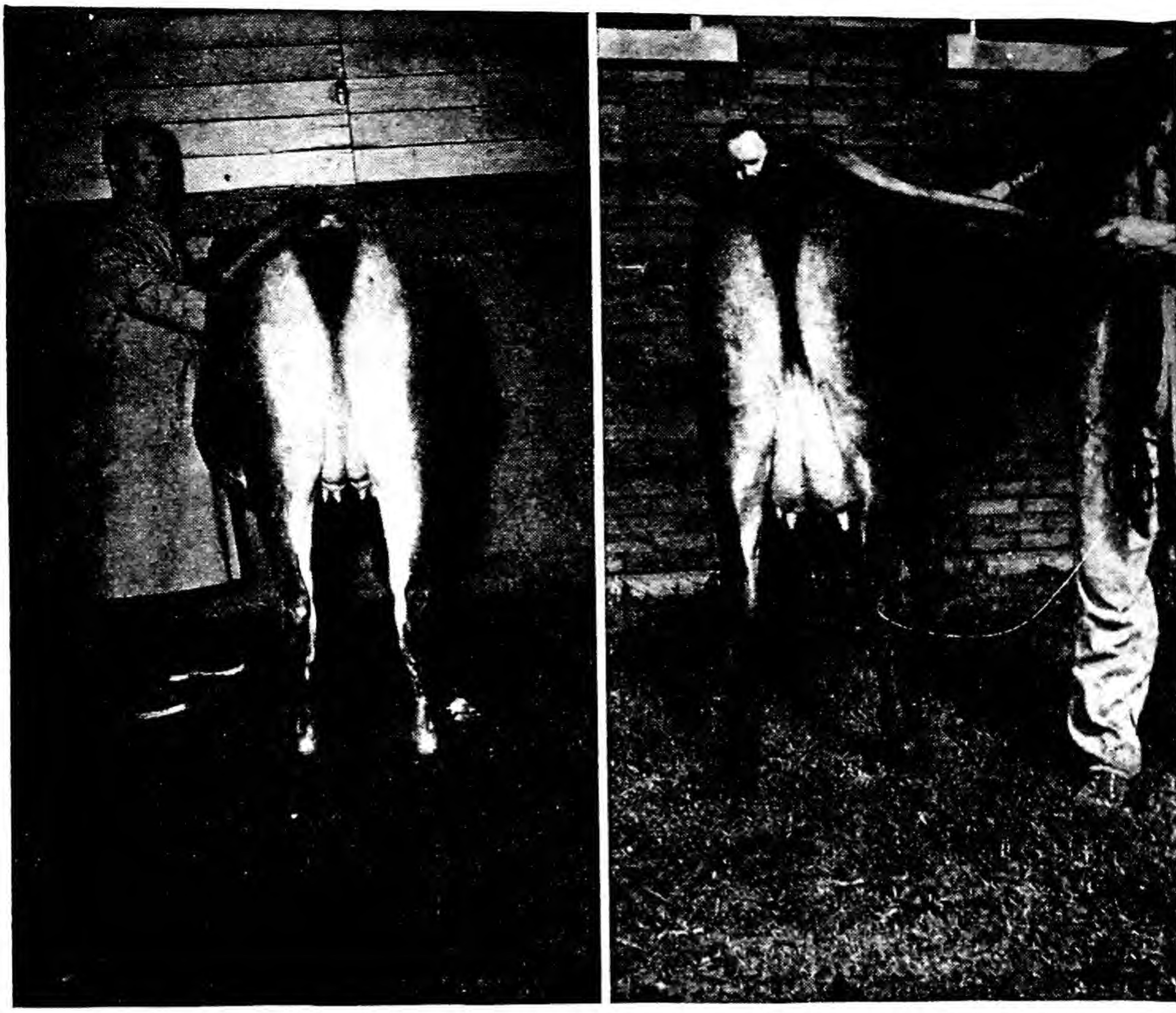


Fig. 75. Udder development with diethylstilbestrol. Sometimes the udder may be fully developed by the subcutaneous administration of estrogens. On the left is shown the appearance of a two year old sterile Jersey heifer on the day injections of 20 mg. diethylstilbestrol three times weekly were begun. On the right is shown the appearance of the same animal three months later with fully developed udder, milking as well as any of her sisters following normal calving. Injections were continued for only three weeks.

While this development is going on, there is comparatively little secretion of milk or milklike products. Not until shortly before parturition is milk secreted to any extent. At the time of parturition the udder is developed to its full extent.

Causes of the udder development. In the rat and other laboratory animals it has been demonstrated that in the castrated (otherwise normal) animal two hormones are needed for complete development of the mammary gland. Estrogen, the female sex hormone, causes the development of the ducts. The normal estrogen is estradiol, secreted by the follicle of the ovary. Several synthetic estrogens are now available at low cost. The second hormone, known as progesterone, is produced by the yellow body (corpus luteum). It causes the development of the lobular alveolar system.

Other pituitary hormones, thyroxin and adrenal hormones, are also necessary but in the normal animals are presumed to be always present.

For the cow the hormonal requirements have not been adequately established but it is assumed that they are the same as for the rat. So far, no one has developed a system of hormone treatment that will insure the full development of the udder in infertile cows which is very desirable from a practical standpoint. In some cases, especially in heifers, the administration of synthetic estrogen, diethylstilbestrol, has produced full development and complete lactation. In other and for the most part older infertile cows only partial development occurs to this treatment. In some cases administration of progesterone together with estrogen enhances the growth and in other cases no benefit from this hormone is noted.

Involution. Following the height of milk production, there is a gradual recession of the size of the udder and the amount of milk secreted, and following the cessation of milking there is a rapid shrinkage of the glands. This is due to the disappearance of the alveoli. With the recurrence of pregnancy the alveoli again develop, due to the secretion of the hormones, estrogens, and progesterin.

Chapter 32

THE PHYSIOLOGY OF MILK SECRETION

As milk is one of the most complex of naturally occurring substances, it is only to be expected that there has been much speculation as to its synthesis and that much remains to be learned. Not only is milk a complex substance (see Chapter 45), but many of its constituent parts are very complex and found nowhere else but in milk. The more important of the milk constituents are the proteins (casein, albumen, and globulin), milk fat, milk sugar or lactose, and the salts. There are in addition many minor constituents, such as the pigments, vitamins, and other organic compounds, that are always present in milk.

Fundamental knowledge about the many factors involved in lactation is of recent origin. Before the more important facts were known a great deal of speculation took place which resulted in the formulation of so-called "theories of milk secretion." These theories will be briefly considered and will be followed by a consideration of the recently discovered, more important facts about the complex phenomenon of lactation, which, for ease of discussion, is divided into five parts: endocrine factors, time when milk is secreted, equilibria between milk and blood, relation of pressure to secretion, and synthesis of the milk ingredients.

Theories of milk secretion. Milk secretion refers to the process by which the constituents of milk are synthesized by the cell. It should not be confused with the term "letting down," which will be discussed under a separate heading.

Many theories have been advanced to explain the phenomenon of milk secretion. These theories may be divided into the following four classes:

1. The theory of filtration.
2. Milk is the result of cell degeneration.
3. Milk is secreted by the cells as the result of true cell metabolism.
4. A combination of two or all three of the above.

The filtration theory. One of the oldest theories as to how milk is secreted is that the mammary gland acts as a filter taking out of the blood the different constituents of milk. For this theory to be tenable, the blood would have to contain all the constituents of milk. Since chemical analysis of the blood has failed to reveal the presence of many of the characteristic constituents of milk, such as lactose, milk fat, casein, and many others, this theory must be discarded as inadequate. Some of the blood constituents, such as globulin, urea, many of the salts, and others, are found in milk, and must filter through the mammary cells from the blood.

Cell degeneration theory. In about 1870 a theory was advanced that milk is formed by a breakdown of the alveolar cells through a fatty degeneration process. This theory, widely accepted for a time, accounted for a continuous secretion of milk by postulating a rapid cell division, with the cells next to the alveolar cavity liquefying to form milk. This led to the concept that milk was liquid meat. The theory found support in the finding of cellular material in milk, but it has now been shown to be inadequate in accounting for milk secretion. Microscopic examination of the mammary gland does not give evidence of cell division that would account for the amount of milk secreted. It would require the degeneration of billions of cells for the production of milk for one milking of an ordinary cow.

True cell metabolism theory. That milk is formed, in the main, by true cell metabolism of the alveolar cells is the generally accepted theory of today. There are many different ideas among the proponents of this general theory as to how the cell synthesizes milk. It is agreed that the blood precursors of the different milk constituents "filter" into the alveolar cells where they are acted upon in whatever way is necessary to change them to the milk constituents. There are two general ideas as to how the newly formed milk is liberated from the alveolar cells into the cavity of the alveolus. One is that, as the milk is formed, it continuously oozes out of the cell into the alveolar cavity. The other idea is that, as milk is formed in the cell, it is forced to the lumen end (the end in the alveolus), causing an elongation of the cell, which finally ruptures or decapitates to free the milk into the alveolus.

A combination of true cell metabolism and other factors. Although there is little question that the synthesis and secretion of milk is, in the main, due to special metabolism of the alveolar cells, there is also evidence that some parts of normal milk come from cell degeneration and infiltration of blood constituents. It is to be expected that some of the millions of alveolar cells in the udder are constantly degenerating to become a part of the milk. Although such degeneration is normal in the formation of milk, it cannot be said to be essential for the synthesis of milk. A number of the ingredients of milk apparently come from the blood without being altered. Most conspicuous of these is milk globulin, which is a constant constituent of milk and which is identical with the globulin of the blood. Other milk constituents, such as the vitamins, mineral salts, and the various flavoring compounds from the feed, are not essential constituents for the synthesis of milk and come into the milk from the blood in an unaltered form.

Recently discovered facts about lactation. *Endocrine factors.* A fully developed udder will not secrete milk without the action of hormones. It is well established that a hormone known as prolactin secreted by the anterior pituitary gland is essential for the initiation and the maintenance of lactation. This hormone is also commonly known as the lactation hormone. Many cows, undoubtedly, are poor milk producers because they lack the ability to produce enough of this hormone. Several experiments have shown great increases in milk production in some cows following injection of prolactin.

Thyroxin, the hormone secreted by the thyroid gland, is also needed. When the thyroid gland is removed, the cow dries up. Administration of thyroxin or thyroid glands will restore and maintain lactation in the operated animals. Recent experiments have shown many cows to respond with increased milk and fat percentage when cows are fed thyroprotein or iodinated casein. This substance contains the hormone thyroxin.

The adrenal gland secretions are also required for maintenance of lactation. Removal of these glands in a number of species invariably causes lactation failures which may be prevented by the injection of adrenal cortex extract. Whether adrenal hormone deficiency exists in the cow is not known.

Other hormones secreted by the pituitary and other glands are undoubtedly also needed for full lactation. An excess of the estrogenic hormone has a depressing effect upon milk flow.

Several investigators have reported not only the full udder development from the administration of diethylstilbestrol, a synthetic estrogen, but in some cases as high levels of milk production as would be expected following a normal calving. The full explanation for this behavior is not at hand, but it must be assumed that the other hormones needed for lactation were secreted in adequate quantities. This latter view finds support in that often no (or very little) milk secretion takes place, presumably because of the lack of sufficient secretion of the needed hormones.

Time when milk is secreted.[1] Until recently it was thought that most of the milk obtained at a milking was secreted during the milking act. One of the reasons for such a belief was that the udder did not have the capacity to contain all of the milk that was obtained. Another reason was the observance that shortly after milking was begun the teats and udder became distended—leading to the interpretation that a sudden rapid secretion of milk had taken place. A series of experiments conducted by a number of different investigators has shown conclusively that all of the milk gotten at a milking is present in the udder when the milking begins and that none is secreted during the milking process.

That the udder has capacity for all of the milk has been shown by injecting back into it more than was removed. That all of the milk is in the udder has been demonstrated by slaughtering high producing cows at milking time and removing the udder. Investigators have been able to account for more milk than the cow was expected to produce had she been milked before slaughter. Other experiments have shown that at milking time the pressure within the udder is of such a magnitude that milk cannot be secreted.

Pressure and milk secretion.[2] Not only is all of the milk obtained at a milking present in the udder at milking time, but it is now known that as soon as milking is completed the secretion of milk begins. After evacuation

[1] Petersen, W. E., Palmer, L. S., and Eckles, C. H. Am. Jour. Physiol. 90:573. 1929. Swett, W. and Graves, R. R. Jour. Agr. Res. 45:385. 1932.

[2] Garrison and Turner. Mo. Agr. Expt. Sta. Res. Bul. 234. 1936. Petersen, W. E., and Rigor. Proc. Soc. Expt. Biol. and Med. 30:257. 1932.

of the milk, the alveoli are more or less empty and the new secretion takes place without meeting any back pressure. As the alveoli fill up, they become distended and the back pressure of the milk therein first slows down the rate of secretion and finally stops it completely. When the intra-alveolar pressure reaches 30 to 40 mm. in mercury pressure, milk secretion is completely stopped and re-absorption begins.

The inverse relationship between intra-alveolar pressure and the rate of milk secretion accounts for the greater milk production obtained by the more frequent milking per day. The evidence now available indicates that when cows are milked at six-hour intervals, no back pressure in the alveoli develops and the maximum production is attained.

Equilibria between milk and blood.[1] When milk is isotonic with blood, each having osmotic pressures of 6.6 atmospheres, the two are not in equilibrium. On a molar basis [2] milk contains 20 times the fat, 40 times the sugar, 7 times the potassium, 7 times the phosphorus, 14 times the calcium, and 4 times the magnesium contents of the blood. Blood contains twice the protein, 4 times the chlorine, and 8 times the sodium contents of milk. There is, therefore, a constant force present to bring these various substances toward the same levels in milk and blood. The *p*H of milk is normally 6.5 while that of blood is 7.4. Approximately three-fourths of the osmotic pressure of blood comes from the chlorides while the same portion of the osmotic pressure of milk is produced by lactose.

Other blood substances are found in the same concentrations in the milk. This is the case for urea, uric acid, creatine, and several other naturally occurring blood constituents. Many substances of dietary origin in the blood find their way into the milk by simple diffusion. Among these are various feed flavors in the plasma portion of the milk. Those feed flavors that are fat soluble may be concentrated in the milk in a degree many times that found in the blood. It has long been known that to avoid milk flavors from certain feed stuffs, the animals should be fed *after* rather than *before* milking. This fact is explainable by the fact that the flavoring constituents will then have time to be passed out of the blood, and as the levels in the blood become lower the substances will pass back from the milk. Many substances find their way into the blood via the lungs.[3] Among the substances that will pass into the blood through this channel are barn odors, turpentine, and many aromatic compounds. Once in the blood the behavior with respect to getting in and out of the milk is identical to that of substances having their origin in the feed.

A third group of substances in the blood are not normally found in milk. Most prominent of these are sodium bicarbonate and blood albumin. The normal mammary gland membranes do not permit the passage of these substances.

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[1] Petersen, W. E. Jour. Dairy Science. 25:71. 1942.
Petersen, W. E. Recent Prog. Hormone Res. 2:133. 1948.
[2] Simms. Internatl. Dairy Cong. Proc., 2nd. Sec., 50. 1931.
[3] Brereton and Petersen. Jour. Dairy Science. 25:381. 1942.

Factors that tend to produce equilibrium. Mastitis, failure to remove the milk, and injection of various substances into the udder tend to shift the composition of the milk more toward that of the blood. In mastitis, depending upon the severity of the attack, lactose of the milk will be decreased, as will calcium, phosphorus, and casein. Chlorine, sodium, and globulin will be increased and blood albumin and sodium bicarbonate not normally present in milk will be found there. The *p*H of the milk will increase toward that of the blood.

Failure to remove the milk for many days tends to produce changes in a similar direction. This phenomenon explains, at least in part, the composition of colostrum. In the production of colostrum the secretions accumulate for long periods and equilibria forces come into play. Milking daily during the period before calving prevents the formation of colostrum. Apparently the exchange of milk and blood substances not in equilibrium begin when the intra-alveolar pressures become sufficient to stop the secretion of milk. Equilibria phenomena do not wholly explain the different compositions of colostrum from that of normal. Total protein of colostrum is much higher than that of blood, as is also the case with vitamins (especially A) and antibody proteins.

Blood flow through the udder. One of the astounding recent discoveries is that of the enormous amounts of blood flowing through the mammary gland. Shaw and Petersen,[1] on the basis of calcium uptake from the blood, estimated 387 volumes of blood for each volume of milk. Graham et [2] al. calculated 500 times as much blood as milk. Assuming 400 volumes of blood to one of milk, a cow producing 50 pounds of milk daily must pump 10 tons of blood through the udder.

Synthesis of the milk constituents. In recent years much work has been directed toward a study of the synthesis of the different milk constituents from the blood precursors. While the knowledge in this field is still far from complete, there is enough known to show that the process of the making of milk is very complex. Knowledge has been gained from experiments on living cows in which analyses for various blood constituents are made of simultaneously drawn arterial and mammary vein bloods by means of the perfusion technique, in which the isolated udder is perfused with bloods that are circulated over and over with or without additions. Other experiments succeeded by altering the blood in the intact animal, for example, by the administration of insulin to lower the blood sugar and by the incubation of mammary tissue with the addition of the various materials to be studied. A brief consideration of the knowledge gained from these studies on the way fat, proteins, lactose, and minerals of milk are accounted for will add to a better understanding of the physiology and biochemistry of lactation.

Milk fat. Milk fat differs from other fats in that it consists of mixed triglycerides, having all the even numbered carbon fatty acids from the 4 carbon fatty acids (butyric) to the normal 18 carbon fatty acids character-

[1] Shaw and Petersen. Amer. Jour. Physiol. 123:183. 1938.
[2] Graham, Jones, and Kay. Roy. Soc. London Proc., Series B. 120:330. 1936.

istic of body fats. The question of the source of milk fat and the method of its synthesis has been one of debate. Some have postulated that the milk fat might come from carbohydrates and others that it comes from fat of the blood. Comparison [1] of the fat content of the arterial blood as it enters the udder with that of the venous blood coming from the udder, shows a diminution in the amount of blood fat that can account for the milk fat. Blood fat, however, does not possess the lower fatty acids characteristic of milk fat. If the blood fat is the source of all milk fat, then it is altered by the mammary cells.

Work at the Minnesota Station has shown that fatty acids are present in the basal part of the epithelial cell.[2] The lower fatty acids of milk fat could be accounted for by oxidation and reduction of the blood fats, as it is well known that fatty acids are reduced by two carbons at a time by this process. Further evidence that fats are altered in the mammary glands comes from analysis of mammary glands.[3] The fats of the active mammary gland have been shown to be intermediate between body fat and milk fat, measured by the chemical methods usually employed. Perfusing a surviving mammary gland with saline solution changed the fat of the gland to still more nearly resemble milk fat. The fat from the udders of nonlactating cows resembled body fat.

Milk fat may be said to be synthesized somewhat independently of the other milk ingredients. This is supported by the fact that each fat globule of milk is surrounded by materials (sometimes called membrane), of which phospholipids are characteristic, that are not in the rest of the milk. By agitation the materials around the fat particle will be more or less evenly dispersed throughout the milk.

The amount of fat in the milk is influenced by factors that do not affect the proportions of the other milk constituents. High fat content in the diet increases the fat content of milk, while fish oils in the diet decrease the fat content of the milk without affecting the other constituents.

The main evidence opposing the theory that blood fat is the only source of milk fat is the high respiratory quotient of the mammary gland (R.Q. = 1.2), which is usually interpreted as indicating the formation of fat from carbohydrates. The breakdown of fat by oxidation and reduction should produce a R. Q. of less than 1.0. As will be pointed out later, there is just enough of carbohydrate material taken up from the blood to account for the lactose in the milk. This fact, taken with the greater uptake of neutral blood fat than is required for the butterfat, outweighs the evidence against blood fat being the sole precursor of butterfat.

Milk proteins. The blood precursors for and the mode of synthesis of milk proteins are still obscure. Two milk proteins, casein and lactalbumin, are different from any blood protein and, therefore, are synthesized from some blood precursors. Lactoglobulin, the third protein found in milk, is identical to blood globulin and may be assumed to get into the milk by

[1] Shaw and Petersen. Jour. Dairy Science. 23:1045. 1940.
[2] Kelley and Petersen. Jour. Dairy Science. 22:7–16. 1939.
[3] Petersen, Palmer, and Eckles. Am. Jour. Physiol. 90:582, 592. 1929.

diffusion from the blood. Earlier workers,[1] finding that the udder takes up amino acids from the blood, concluded that milk proteins were made from blood amino acids. Others,[2] however, showed that the uptake of amino acids was enough to account for only a portion of the milk proteins. Studies on the formation of urea [3] by the udder revealed that about enough of this substance is formed to account for all of the amino acid uptake to raise the question as to whether these amino acids are used in protein formation. Evidence, although meager at the present, points to large quantities of blood globulin being taken up by the mammary gland which suggests a transformation of it to the other milk proteins.

Milk sugar. As the result of a series of experiments at the University of Minnesota,[4] the question of the mode of lactose synthesis is fairly well understood. By the use of the perfusion and tissue-culture techniques, it has been found that lactose is formed from glycogen in the secreting cells of the gland. Incubation of tissue rich in glycogen resulted in lactose formation. Blocking the breakdown of glycogen by the administration of insulin in perfusion experiments, stopped the production of lactose in spite of the presence of large quantities of glucose and other carbohydrate material in the blood. It is now clear that any material in the blood that can form glycogen can be used for the formation of lactose.[5]

The lactating gland contains about 0.2 per cent of glycogen while the dry gland has but a trace of this substance. The earlier explanation that insulin administration to cows caused a lowering of milk sugar by a lowering of blood sugar is not correct. It is true that the blood sugar is lowered but the effect of lowering milk sugar is due to insulin blocking the conversion of glycogen to milk sugar.

"Let-down" of milk. There have been many speculations advanced to account for the response to the milking or nursing act in which the gland and teats become turgid. The oldest explanation was that the milk secretion was stimulated to enormous rates as the result of a nervous stimulus. With the establishment of the fact that all of the milk to be obtained is present in the udder when the stimulus is applied, such a postulate was no longer tenable. Hammond [6] advanced the idea that the turgidity was due to an engorgement of blood and the force-down of milk. He postulated that the milk was forced out of the alveoli by engorgement of blood into the inter-alveolar spaces. Other ideas were advanced to account for not getting more than a part of the normal amount of milk, as

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1 Cary. Jour. Biol. Chem. 43:477. 1920.
Blackwood. Biochem. Jour. 26:357. 1932.
2 Graham, Houchin, Petersen, and Turner. Am. Jour. Physiol. 122:150. 1938.
Graham, Petersen. Proc. Soc. Expt. Biol. and Med. 38:632. 1938.
Shaw and Petersen. Proc. Soc. Expt. Biol. and Med. 38:632. 1938.
Shaw and Petersen. Am. Jour. Physiol. 123:183. 1938.
3 Graham, Houchin, and Turner. Jour. Biol. Chem. 120:29. 1937.
Shaw and Petersen. Proc. Soc. Expt. Biol. and Med. 38:632. 1938.
4 Review by Petersen. Physiol. Rev. 24:340. 1944.
Knodt and Petersen. Jour. Dairy Science. 28:415. 1945. 29:115, 121. 1946.
5 Petersen, Hewitt, Boyd, and Brown. Jour. Am. Vet. Med. Assn. 79:217. 1931.
6 Hammond. Vet. Rec. 16:519. 1936.

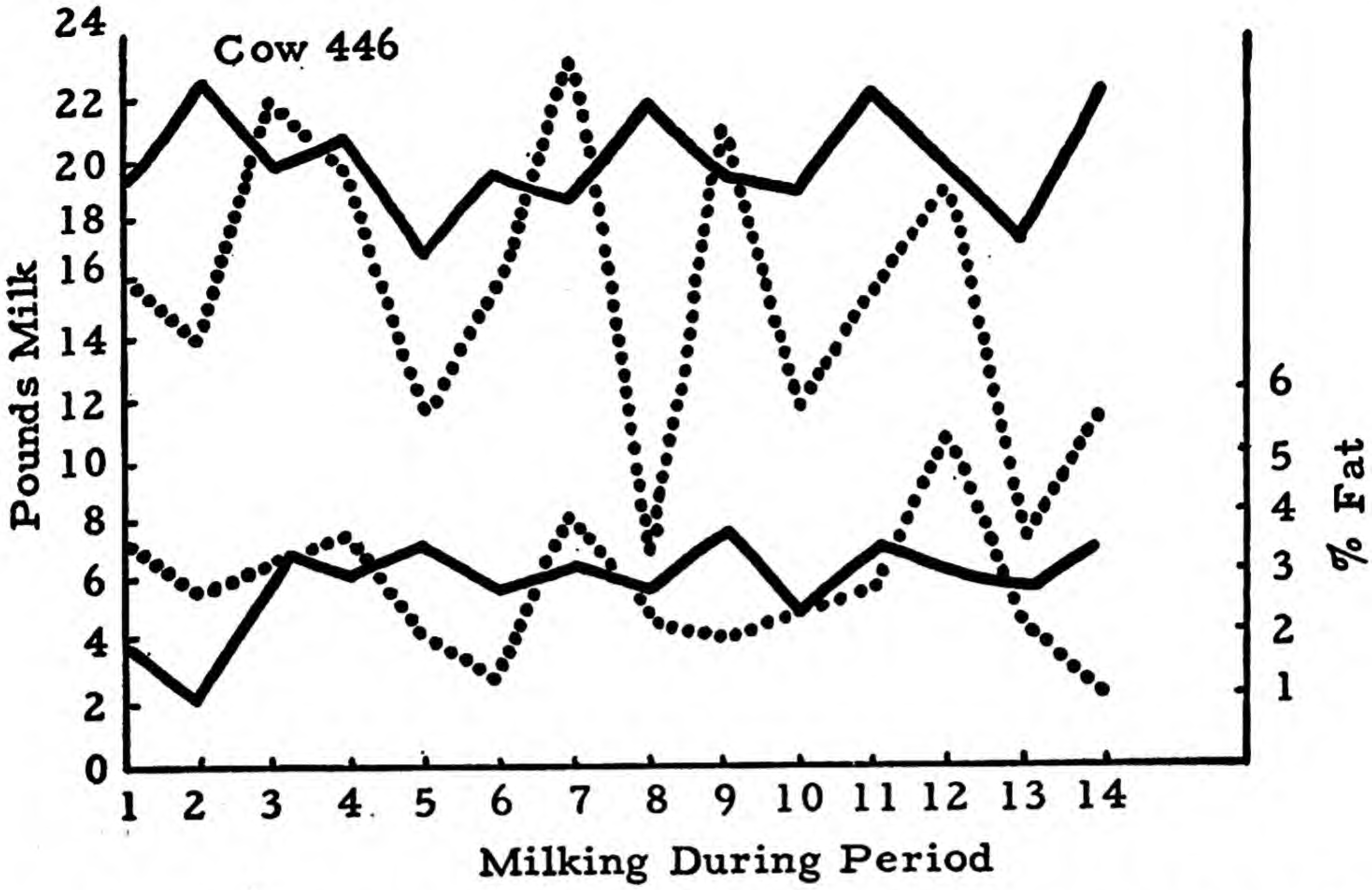


Fig. 76. Here is shown the effect of waiting 20 minutes after stimulation for let-down before beginning milking. Solid lines represent milk weights and fat percentages for 14 consecutive milkings done one minute after stimulation for let-down was made. The dotted lines present the same facts for 14 consecutive milking with a 20 minute interval between stimulation and the beginning of milking.

is frequently observed. In these postulates the cow was credited with the ability to shut off the milk ducts. Needless to say all of these postulations have been found wanting.

The experiments at Minnesota and Kentucky[1] showed that the let-down of milk is due to a reflex act involving a stimulus, a hormone from the pituitary gland, the blood, and the smooth muscles in the mammary gland. The teats are richly endowed with nerve endings that perceive touch, pressure, and warmth. These perceptors are maximally stimulated by the natural nursing act of the calf. This stimulus causes the posterior pituitary gland to secrete into the blood a hormone known as oxytocin which is carried by the circulation to the udder where smooth muscle cells are contracted to squeeze the alveoli forcing the milk out into the ducts.

Amputated udders, when perfused with blood, will respond with a complete expulsion of the milk following injection of oxytocin into the circulating blood. Not until the discovery of this fact could perfusion experiments be carried on because of the failure to get the milk out. When injected into the jugular vein, it requires about 45 seconds for the hormone to reach the udder. This agrees very well with the time interval observed

[1] Ely and Petersen. Jour. Dairy Science. 24:211. 1941.

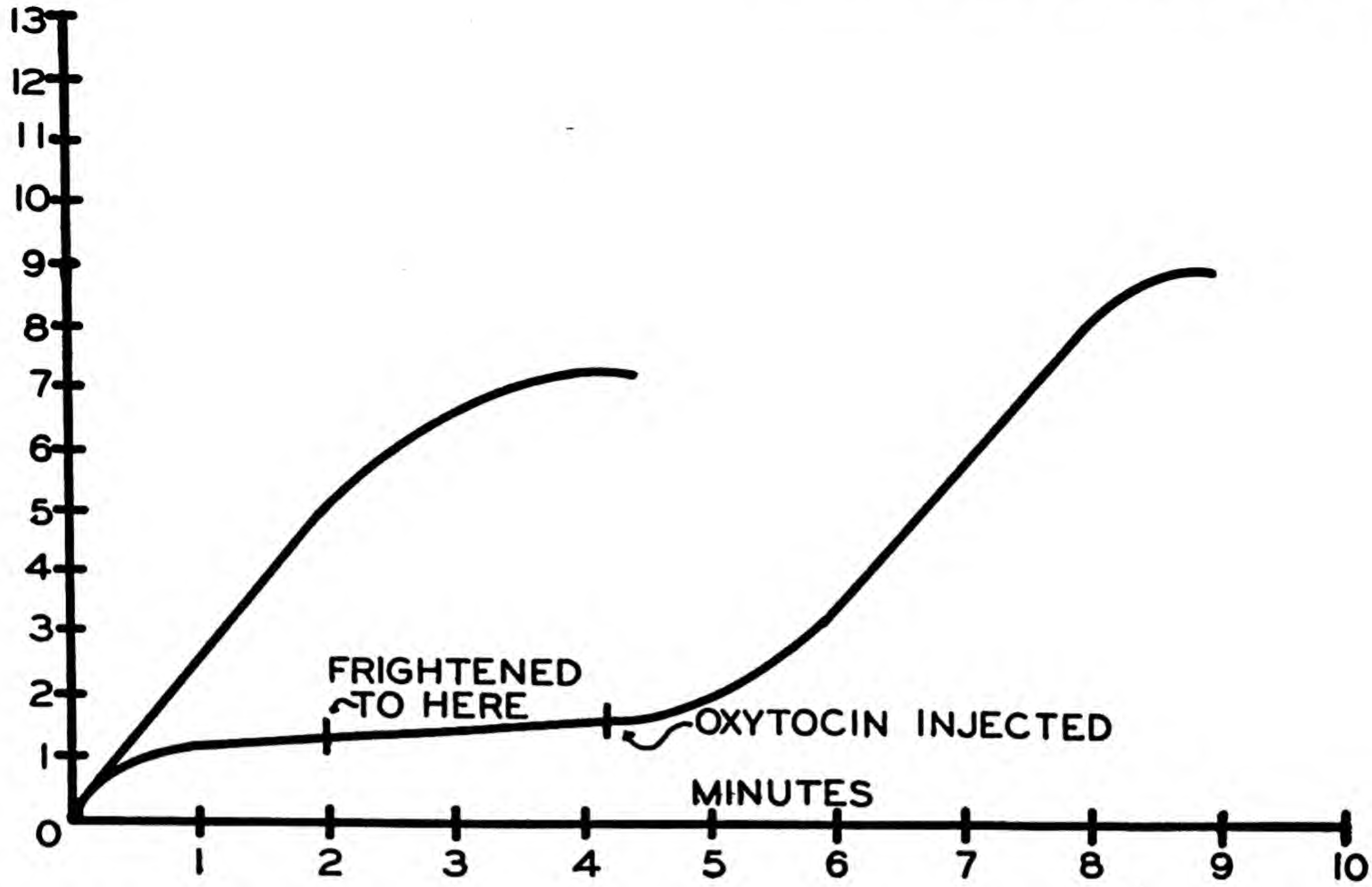


Fig. 77. Fright prevents response to the milking stimulus. The upper curve presents the rate of milking following proper stimulation one minute before milking began. The lower curve shows results when the cow was frightened by unusual noises before and two minutes after milking began. Following the administration of oxytocin the milking progressed normally.

between the application of the stimulus and the appearance of the turgid condition of the lower part of the udder and the teats.

Factors affecting the response. Since the response to the milking stimulus is a reflex act, it is to be expected that it can be conditioned. Experiments have shown that response can be either partly or completely blocked by varying degrees of excitement and the promptness and completeness of the response can be altered by milking techniques. When cows were frightened by explosion of paper bags, stuck with pins, or had a cage of bats placed in a manger, the response was completely blocked. Only the milk that had drained down into the ducts and sinuses was obtained. Intrajugular injection of ten units of oxytocin caused a complete let-down of the remainder of the milk. Milder excitement, such as that caused by placing grain feed out of reach but in plain sight caused a slow response prolonging the milking time and finally resulting in an incomplete force-out of the milk.

It has also been demonstrated that prolonged stimulation, such as is the case with slow milkers, or prolonged stripping, will cause cows to develop habits of responding with a slow let-down over a long period of time and incomplete emptying of the gland. These facts form the basis for the recommended milking procedures in Chapter 35.

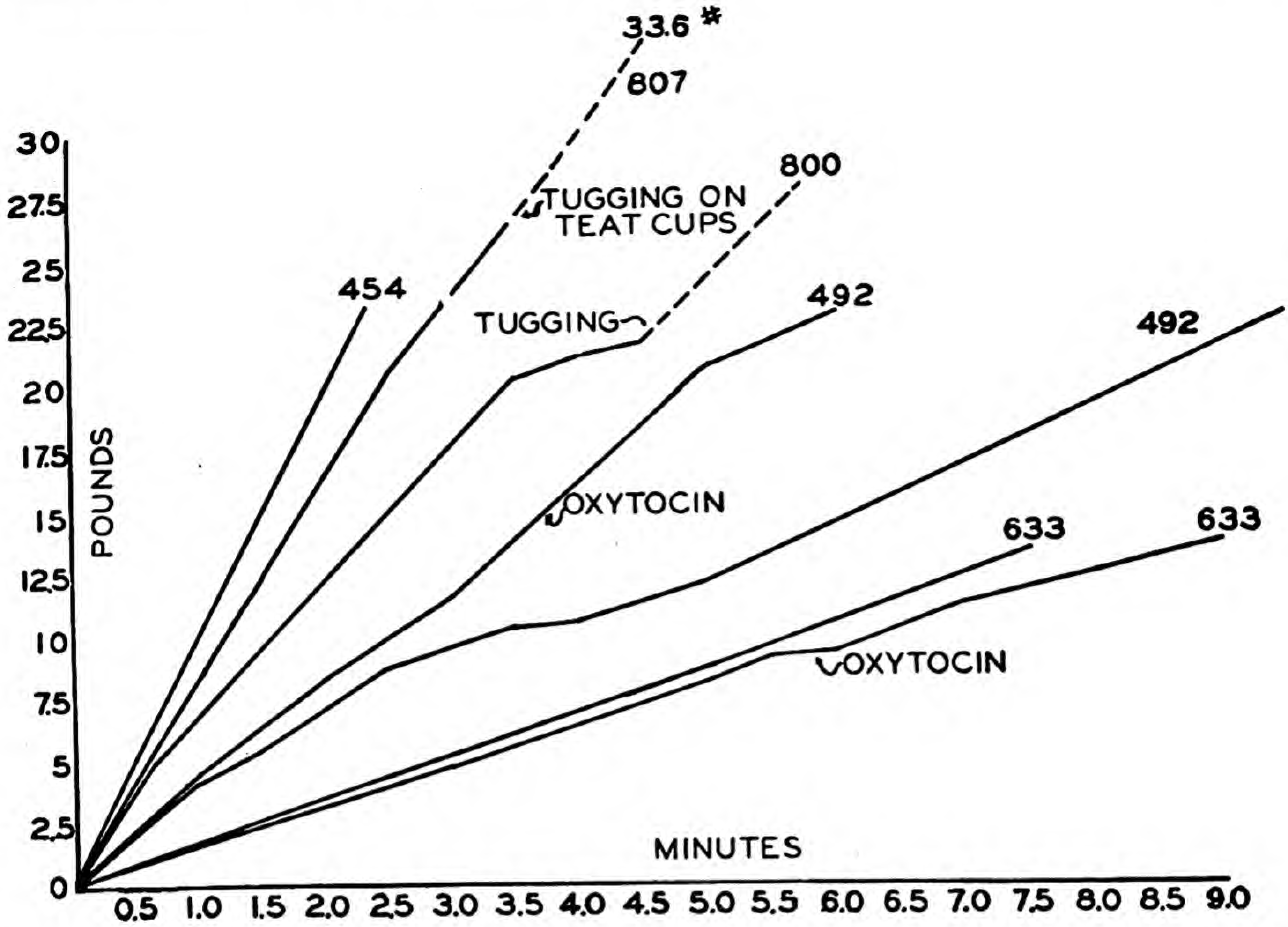


Fig. 78. Cows milk at different rates. Curves showing different rates of milk withdrawal by machine milking. The rates of milk withdrawal for 492 was markedly increased following the injection of oxytocin to show that she responded normally with a slow let-down of milk. The milking rate for 633, a hard milker, was not increased following oxytocin. The time required for milking 492 can be shortened by proper training, for 633 training is without effect.

Time factors in response.[1] When it was demonstrated that from 45 seconds to 1½ minutes are required for the actual let-down of milk to occur following the stimulus, the question naturally arose as to the time the hormone is effective following its release into the blood stream. Two types of experiments have been used to furnish the answer. In one, definite time lapses are allowed between the stimulus and the beginning of milking. In the other, each quarter of a cow is milked separately and in order, and the amount of milk is noted. Following milking, the oxytocic hormone is injected and the remainder of the milk removed and amounts noted. In the latter case, it was found a decreasing proportion of the milk contained was obtained with each successive quarter milked. With the former experiments with a 20 minute interval between the stimulus and the beginning of milking incomplete milking and a rapid decrease in daily milk production set in. From these experiments it is calculated that not more than 8 minutes should elapse between the application and the finishing of the milking or not all of the milk will be obtained.

[1] Miller and Petersen. Jour. Dairy Science. 24:225. 1941.

Effects of incomplete milking. Not getting all of the milk out of the alveoli at each milking speeds up the drying-up process. It has long been known that stopping milking for ten days to two weeks will cause cows to dry up completely. This technique is now generally used when it is desired to dry up cows for a rest period before calving. Failure to get all of the milk out at each milking tends to dry up cows in the same manner but at a slower rate.

If the alveoli are not emptied, it is obvious that they will be filled sooner by the new secretion than when completely empty. The effect is, first, to develop a pressure within the alveoli to reduce the rate of secretion. The pressure also is apt to reach the level where milk secretion stops and some of the ingredients in the blood are exchanged for some ingredients in the milk. This exchange is assumed to upset the secretory mechanism in the cell and to set in motion the involution of the secretory cells.

Chapter 33

FACTORS INFLUENCING THE QUANTITY AND QUALITY OF MILK

IT IS WELL KNOWN THAT MILK FROM DIFFERENT COWS AND BREEDS MAY vary widely in chemical composition and in amounts produced. That milk from the same cow is subject to variation in chemical composition and amounts produced is not so generally recognized. Some of the variations from day to day are called "normal variations," and no causative factors have been ascribed to them. Other variations in both quantity and quality are due to large numbers of factors. It is the object of this discussion to consider the factors that affect the quantity and quality of milk. Among the factors that affect amounts of milk and the composition of milk may be listed:

1. Heredity
2. Stage and period of lactation
3. Time and frequency of milking
4. Condition of the cow
5. Climate
6. Environment
7. Feed
8. Disease

Normal variations. That there are daily variations in both quantity and quality of milk that cannot be attributed to a definite cause, is well known. It is not uncommon for fat percentage to vary from day to day as much as 30 per cent, and for milk production to vary as much as 20 per cent. Usually a low fat percentage accompanies a low milk production when daily variations are considered. This is accounted for by the probability that a low milk production is due to a failure of the letting-down of all the milk, the latter part of which is high in fat content. Thus, the high fat milk will be retained and let-down on the following day to give a relatively large amount of milk with a high fat content.

The other constituents of milk also may vary from day to day, although the magnitude of their variations is not so great as that of the milk fat and amount of milk. In the order of the degree of variation, proteins are first, lactose is next, and the salts are the least variable.

HEREDITY

Hereditary factors. The variations of both quantity and quality of milk produced by the representatives of the different breeds are given in the table on the next page.

It will be observed that there is an inverse ratio between the quantity of milk and the fat percentage. The variations within the breeds are considerable. While the Jerseys average 5.36 per cent of fat, there are indi-

vidual Jerseys producing milk with less than 4 per cent of fat, and also those that exceed 7 per cent. Variations for the other breeds are proportionately great. The amounts of milk vary to a much greater extent than does the fat percentage and, therefore, it is more important to know the milk production of a cow than the fat percentage of her milk in order to evaluate her.

Persistency, which is an inherited character, affects materially the total milk produced for the lactation period. Cows with the same initial production may vary as much as 50 per cent in the production for the year because of a difference in persistency.

COMPOSITION OF MILK BY BREEDS

Breed	Total Solids	Fat	Protein
	Per Cent	*Per Cent*	*Per Cent*
Jersey	14.80	5.36	3.80
Guernsey	14.50	4.98	3.75
Brown Swiss	13.00	4.00	3.50
Ayrshire	13.00	4.00	3.50
Holstein	12.30	3.42	3.30

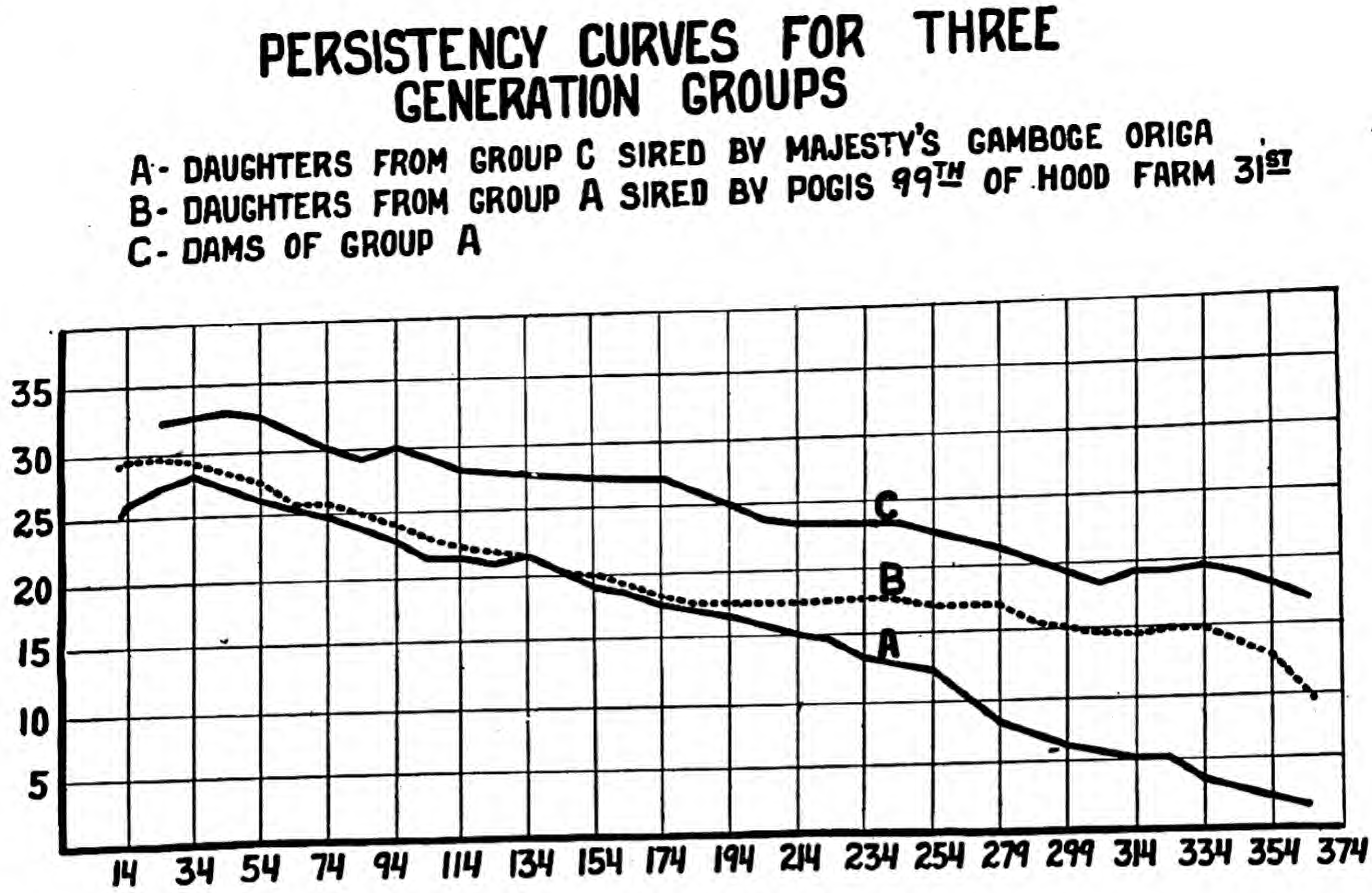
Breeds and individual cows differ widely in the capacity for secretion of the yellow pigment, carotene, into the milk. The Guernseys are noted for their ability to produce yellow colored milk and butter from feeds rich in carotene. The Jerseys rank second and the Holsteins last in this regard.

The fat particles in milk vary from 1 to 10 microns in diameter. The fat particles in Guernsey milk are the largest, while the Holstein and Ayrshires have the smallest fat particles. The size of the fat particle in general varies with the fat percentage of the milk, the higher fat milk having the larger fat particles. A quart of milk has from five to ten trillion fat particles.

STAGE OF LACTATION

Stage of lactation. The stage of lactation affects both the yield and the composition of milk and milk fat. A normal lactation curve, together with the fat percentage curve, is given in Figure 79. It will be noted that after the first 50 days of lactation, there is a decline in daily milk production until the end of the lactation period. The curve for fat percentage is somewhat inverse to the curve for daily milk yields, as about the time that daily milk yields begin to fall, the fat percentage begins to rise. The tendency is, therefore, for the daily fat production to be more constant than either the fat percentage or the daily milk yields. With the advance of lactation, there is also a decrease in the size of the fat particles in the milk. The daily total number of fat particles produced has a tendency, therefore, to be even more constant than the daily fat production. Eckles and Shaw [1] observed that the fat particles of milk in the twelfth month of lactation were about

[1] ECKLES AND SHAW. U. S. Dept. Agr., B.A.I. Bul. 155. 1912.



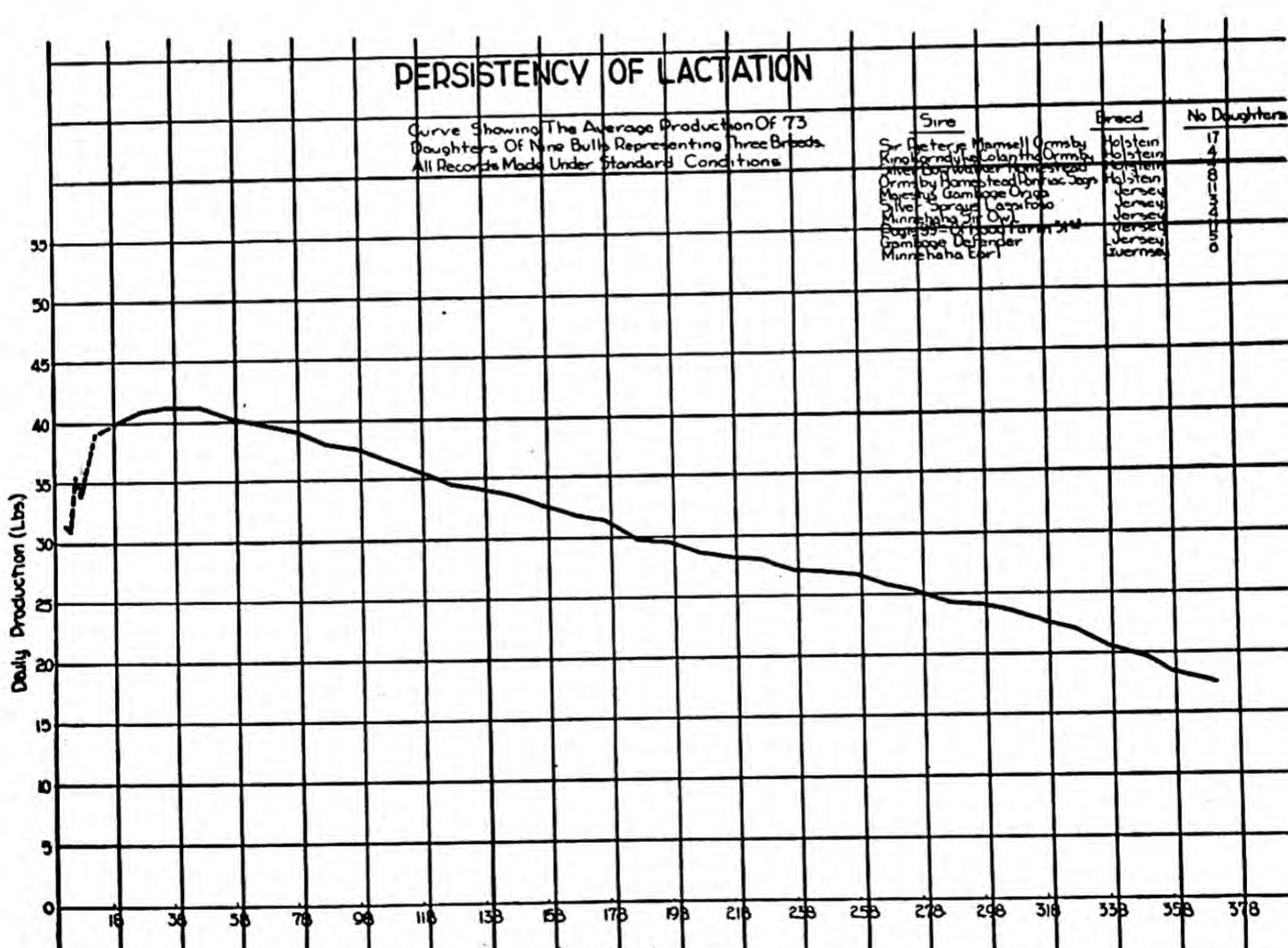


Fig. 79. Persistency curves. (*Upper*) The persistency curves for three generation groups of Jerseys, showing marked variations between the different groups. (*Lower*) Composite lactation curve of 73 cows from 3 different breeds owned by the University of Minnesota.

one-half the size of the particles during the first month of lactation.

The other constituents of milk also change in amounts as lactation advances. Colostrum milk, which is discussed under a separate heading, changes to normal milk in about ten days and then remains of relatively constant composition to about the 90th day of lactation. From this point the milk proteins increase in percentage amounts until the end of the lactation period. The increase in the percentage of protein with the advance of lactation is greater than the percentage increase of fat. Eckles and Shaw reported an increase of 30 per cent for protein of the advanced lactation milk over the average, while fat showed only a 20 per cent increase. Milk sugar remains practically constant for the entire lactation period, except in the colostrum milk, as also do the mineral constituents.

The chemical composition of the fat also changes with the advance of lactation. There is a decrease in the Reichert-Meissl number which indicates the lower fatty acids. Saponification values also fall for the same reason. The iodine values increase as the lactation advances.

Bitter milk. Frequently during advanced lactation, the milk becomes bitter after standing for a short time.[1] This is due to the action of an enzyme (lipase) which is secreted with the milk and splits the fat into free fatty acids and glycerin. The free fatty acids, which taste rancid, unite with the cations of the milk to form soap. The soap contributes to the "bitter" taste, and in the case of cream it makes for difficulty in churning —in some cases completely prevents the formation of butter.

Effect of parturition upon the composition and properties of cows' milk. If the cow has been given a rest period before calving, the milk following calving differs markedly in its chemical and physical properties from normal milk. If the cow is milked up to parturition, the milk following parturition differs less from normal milk. However, if the cow is milked up to parturition, there is an increase in the heat coagulable proteins, which were found to reach their maximum in the first milking following parturition. Eckles and Palmer [2] studied the chemical composition of milks before and after parturition, when cows were milked up to parturition. They found that with the exception of the heat coagulable proteins the milk under these conditions was normal for all constituents. If the cow is given a rest period before calving, then normal colostrum milk is produced following parturition. The chemical composition of colostrum milk is compared with that of normal milk in the table on page 339.[3] It will be seen that the colostrum milk differs from normal milk primarily in its protein and lactose content. The lactose content of colostrum milk is lower than that of normal milk, and the protein is mainly globulin with a relatively small amount of casein, as contrasted to the reverse proportion for normal milk. In addition to these, colostrum milk contains so-called colostrum corpuscles, which are cell-like particles believed to be partial degenerative products of white blood cells (leucocytes).

[1] PALMER. Jour. Dairy Sci. 5:201. 1922.
[2] ECKLES AND PALMER. Jour. Bul. Chem. 27:313. 1916.
[3] HAMMOND. Vet. Record 16:528. 1936.

COMPARISON OF COLOSTRUM AND NORMAL MILK

Constituents	Colostrum	Normal Milk
	Per Cent	*Per Cent*
Total solids	28.30	12.86
Ash	1.58	0.72
Fat	.15 to 12.0	4.0
Lactose	2.50	4.8
Casein	4.76	2.8
Albumin	1.50	0.54
Globulin	15.06	
Total protein	21.32	3.8

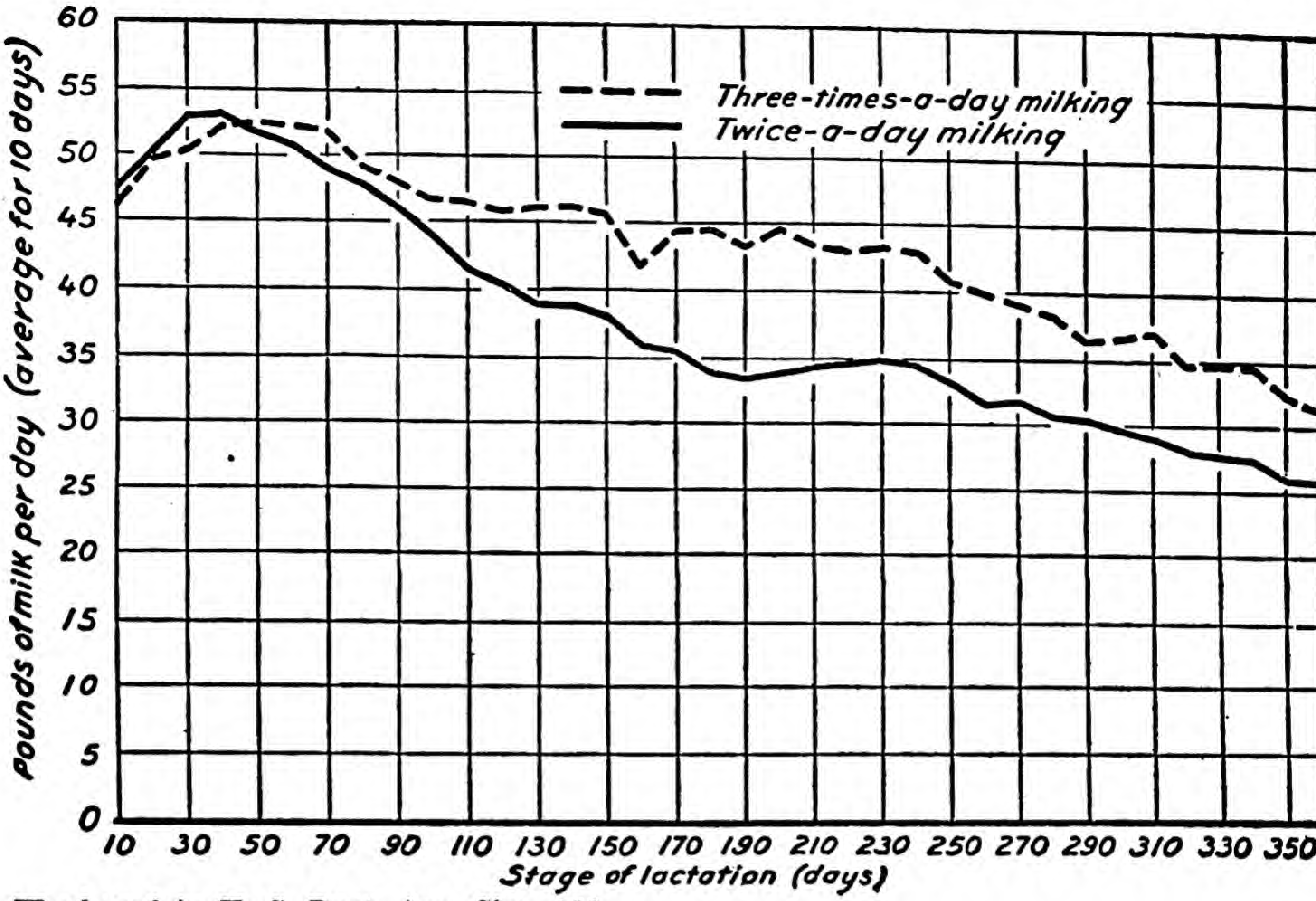
Colostrum milk also has been shown to contain a concentration of vitamin A, which may reach a figure as high as 20 times that of normal milk.[1] This, together with the antibodies which colostrum milk contains, is held to be responsible for the beneficial effects observed in feeding colostrum milk to newborn calves. When cows are milked up to parturition, colostrum does not contain the concentration of either the vitamin or the antibodies.

MILKINGS

Number of milkings per day. A number of experiments have been conducted to ascertain the effect of milking more than twice daily upon a total milk production. All workers have reported increased production for the three-times-a-day milking over the twice-a-day milking; likewise, milking four times a day has been responsible for further increases in milk production. The magnitude of the increase in milk production by increased frequency of milking varies with the different reports.[2] It is apparently dependent upon the individuality of the cows, some cows showing much greater increases than others with increased frequency of milking. As little as 1 per cent increase for three times milking over two times milking and as high as 25 per cent increase have been reported. For four times milking as high as 33 per cent increase over three times milking has been reported. Most of the trials comparing different frequencies of daily milking have been for but short periods of time.

Woodward[3] carried two groups of cows through entire lactation periods. After milking one group twice daily and the other group three times daily, he found much greater increases for the three-times-a-day milking over the entire period than would be expected from the observed increases of short period trials. The results of Woodward's work are illustrated in Figure 80, where it will be seen that cows milked three times daily are much more persistent than those milked twice a day.

[1] DANN. Biochem. Jour. 27:1998. 1933.
[2] COPELAND. Jour. Dairy Sci. 17:815. 1934.
MORGAN AND DAVIS. Neb. Agr. Expt. Sta. Res. Bul. 59. 1931.
ATKESON. Idaho Agr. Expt. Sta. Amor. Rept. Bul. 164. 1929.
[3] WOODWARD. U. S. Dept. Agr. Circ. 180. 1931.



Woodward in U. S. Dept. Agr. Circ. 180

Fig. 80. Effect of the frequency of milking upon persistency. The cows milked three times a day are more persistent than those milked twice a day.

Woodward also reported a trial where a cow was milked but once a day and her production compared with that when she was milked two times daily. He found that when milked but once a day, the cow produced but 5,292 pounds of milk and 207 pounds of fat, as contrasted to 12,078 pounds of milk and 434 pounds of fat when milked twice daily. The significant observation of Woodward's work is that persistency is greatly reduced with the reduced frequency of milking, and that milking a cow but once a day has a tendency to dry her off.

Whether milking more than twice daily will be economically sound depends upon the increased amount of milk that can be obtained from more frequent milking and the value of the milk, as the cost of milking three times daily is 50 per cent higher than the cost of milking but twice daily. It is doubtful whether milking more than twice daily will pay when the product is sold for butter or cheese making.

The interval between milkings. The length of the interval between milkings affects both the quantity and the quality of the milk. According to MacIntosh, when the interval between night and morning milking is 14 hours, the morning's milk will be about 40 to 50 per cent higher in quantity than the evening's milk; the fat percentage of the morning's milk will be about 1 per cent of fat lower than the evening's milk.[1] If the intervals between morning and evening milkings are equal or 12 hours apart, there is a tendency for the morning milk to be lower in fat content

[1] MacIntosh. Trans. Highland and Agr. Soc. of Scot. 1925.

and slightly higher in total quantity of milk.[1] That the evening's milk is higher in fat is usually explained by the fact that the cow has exercised more during the daytime than at night and that the exercise is responsible for letting-down more fat.

Effect of first and last drawn milk. With the progress of a milking, each successive portion of milk has an increased fat content.[2] The variation in fat content of successively drawn milk depends upon the activity of the cow and the manipulation of the udder prior to milking. In Jerseys, if the cow has been standing for two or more hours before milking, the first drawn milk may contain as little as 1 per cent fat and the last drawn milk may contain as much as 12 per cent fat. If the cow is walked or the udder massaged immediately before milking, the spread between the fat content of the first and last drawn milk is greatly reduced. Following the manipulation of the udder, Turner found that the first drawn milk contained 6.3 per cent fat and the last drawn 8.2 per cent fat. Incomplete milking results in a lower fat content of the milk due to the leaving of the highest fat milk in the udder. Discarding the fore-milk is sometimes practiced to increase the fat content of milk from "low testing" cows.

The other constituents of milk on a fat-free basis do not vary with the progress of milking.

Variation of different quarters.[3] Both the amounts and quality of the milk drawn from each quarter vary. On the average the forequarters produce 40 per cent and the rear quarters 60 per cent of the milk. The forequarters may in some cases produce more than the rear quarters. The right and left quarters also vary. Very seldom do two quarters produce the same amount of milk, the variations being up to more than 100 per cent. The fat percentage of the milk from the different quarters varies less, and also independent of the variations in milk yields. The average deviation of one quarter from the other three quarters would be about ± .2 per cent. The relative proportion for the quarters may change from one lactation to another.

The order in which the quarters are milked affects both the amount of milk and its fat content. Both the amount of milk and the fat percentage decrease with the order in which the teats are milked. No appreciable differences have been observed for the other milk constituents when the order of milking the different quarters is varied.

CONDITION OF THE COW

Influence of the condition of the cow at calving time. Eckles,[4] studying the effects of various conditions of the cow at calving upon the yield following calving, observed that the condition of the cow at calving

[1] Sheehy. Sci. Proc. Royal Dublin Soc. 15:585. 1919.
[2] Ragsdale and Turner. Jour. Dairy Sci. 4:22. 1921.
[3] Turner. The Physiology and Biochemistry of Milk Secretion. The Univ. of Mo., Columbia, Mo. 1933.
Beach. Conn. Agr. Expt. Sta. Rpt., p. 135. 1904.
[4] Eckles. Mo. Agr. Expt. Sta. Bul. 24. 1916.

time had a marked influence upon subsequent milk yields and upon the fat content of the milk. A cow in good condition when calving would start with as much as 25 per cent higher daily milk yields than the one in poorer condition, and the relative spread would be maintained for the entire lactation period. It is well known among people caring for official test cows, that cows in very fat condition at calving time produce milk of much higher fat content for a considerable time after calving. This phenomenon was taken advantage of in the production of seven-day official test records, when it was possible to increase the fat percentage of the milk as much as 30 per cent.

Length of dry period. The length of the dry period cannot be entirely dissociated from the condition of calving time, as, in the main, a better condition is obtained with the increased length of the dry period. There are, however, effects upon the production of the subsequent lactation period that are attributable to the rest period. During the dry period the mammary gland is prepared for the next lactation, and only a rest period will permit full development.

A rest period preceding the second calving has a greater effect upon the next lactation than do the rest periods of subsequent lactations.[1] This is accounted for by the fact that during the first lactation period there has been little chance for growth. When lactation is stopped, the heifer grows rapidly and becomes capable of higher production for the next lactation period.

The udder of the first-calf heifer also needs the rest period for further development, which is reflected in higher production for the next lactation period. The average increases in production for second calvers and older cows for dry periods of varying length are presented in the following table.

INCREASED PRODUCTION DUE TO DRY PERIODS OF VARIOUS LENGTHS[2]

Days Dry Period	2nd Calf Heifers	Older Cows
	Per Cent	*Per Cent*
5	5.0	2.6
15	14.1	7.6
25	21.8	11.8
35	28.0	14.5
45	33.2	18.5
55	37.6	21.1
65	41.3	23.3
75	44.3	25.2
85	46.8	26.7
95	48.9	28.1
105	50.6	29.3
115	52.2	30.2

[1] SANDERS. Jour. Agr. Sci. 17: parts 3 and 4, and 18: parts 1 and 2.
[2] Calculated from Sanders' data in Jour. Agr. Sci., Vol. 18, part 1.

Effect of gestation. [1] It is well known that the latter months of gestation have an inhibitory effect upon the production of milk. This inhibitory effect begins about the fifth month of gestation and continues with an increasing rate of inhibition until parturition. The inhibitory effect of advancing gestation varies with individual cows; some decline in milk yields more rapidly than others. Cows with low persistency would naturally be less affected by the inhibitory force.

Eckles reported a 19 per cent decrease in a year's milk production for a group of cows bred to calve within 12 months as compared to the same group when bred to calve more than 15 months' interval.

Two reasons are given for the decline of milk yields with the advance of pregnancy. One is that the added nutrient requirements for the growing fetus compete with the nutrients to be used for milk production. The other is that with the advance of pregnancy there is secreted a hormone which inhibits milk production. The latter is the more probable cause for the major part of the decrease, but the nutrient requirement for the growing

THE EFFECT OF THE LENGTH OF THE SERVICE PERIOD UPON THE PRODUCTION FOR THE LACTATION PERIOD, BREEDING 85 DAYS AFTER CALVING BEING THE STANDARD TO WHICH THE INCREASES OR DECREASES ARE COMPARED [2]

Days Following Calving when Bred	Increase in Milk Production for the Lactation Period for First-Calf Heifers	Older Cows	Increase in Length of the Lactation Period
	Per Cent	*Per Cent*	*Per Cent*
30	−18.4	−21.3	−15.1
50	−10.6	−11.9	− 9.6
70	− 4.2	− 4.6	− 4.1
85	0	0	0
90	1.1	1.1	1.4
110	5.8	6.3	6.8
130	10.1	10.7	12.3
150	11.4	14.8	17.8
170	17.9	18.3	23.3
190	21.4	21.7	28.8
210	24.5	24.5	34.2
230	27.4	27.2	39.7
250	30.0	29.5	45.2
270	32.4	31.8	50.6
290	34.8	33.5	56.2
310	37.0	35.3	61.7
330	38.9	36.8	67.1
350	40.6	38.1	72.6
370	42.5	39.5	78.1
390	43.9	40.8	83.6

[1] BRODY, RAGSDALE, AND TURNER. Jour. Gen. Physiol. 5:441, 777. 1923. GAINES AND DAVIDSON. Ill. Agr. Expt. Sta. Bul. 272. 1926.

[2] Calculated from data by Sanders in Jour. Agr. Sci., Vol. 17, parts 3 and 4, and Vol. 18, parts 1 and 2.

fetus is also a factor. Since the dry matter content of the fetus is small, relatively small amounts of nutrients are required for its building; but there remains the question of maintaining the fetus. The amount of nutrients required for maintenance of the fetus is not known but would probably approximate, proportionately to size, the requirements for the growing animal.

The previous table presents the effect of the interval between calving and breeding upon the milk and butterfat production for the lactation period. These figures are based upon the increase or decrease in production from a service period of 85 days following calving that can be expected for service periods of varying lengths of time. A service period of 85 days would make the second calving in 365 days. The variations in the length of the lactation period due to different lengths of the service period is also presented. It will be noted that a small difference in the effect of length of service periods is found for first-calf heifers and other cows. For service periods of less than 85 days there is a larger per cent decrease in production than the decrease in the length of the lactation period. For service periods longer than 85 days the per cent increase in the length of the lactation period is greater than the increase in production due to the delayed breeding.

Effect of estrus. No general rule can be laid down as to how the estrus affects milk yields or its quality. In the majority of cases the estrus is accompanied by a decrease in milk yield and an increase in fat percentage. Individual cows, however, may vary in opposite directions or show no variation. Copeland [1] found that out of 211 Jersey cows 75 increased and 131 decreased milk production, with an average decrease for all of .63 pounds daily. While daily variations from normal due to estrus occurred up to over ten pounds, 75 per cent varied less than two pounds.

Butterfat percentage averaged .13 more for the days in estrus than for the normal, with 126 showing increases and 81 decreases. The average variation in butterfat percentage was 0.43, with the extreme variation 2.00.

Effect of age. A large number of studies have been directed toward showing the effect of advancing age upon the amount and quality of the milk produced. In general there is considerable individual variation, but a heifer calving at two years of age can be expected to produce about 70 to 77 per cent of the amount she will produce when mature; with the second calf at three years of age, 80 to 87 per cent; with the third calf at four years of age, 90 to 95 per cent; with the fourth calf at 5 years of age, 98 per cent; and at seven years of age, 100 per cent. The fat percentage varies but slightly with age, due to a tendency to lower slightly after the first lactation period. Commencing with ten years of age, there is a tendency for both milk yields and fat percentage of the milk to decline. In extreme old age milk yields may be as low as 50 per cent of the maximum mature capacity.

The table on the next page presents the age correction factors used by

[1] COPELAND. Jour. Dairy Sci. 12:464. 1929.

different breed associations for converting immature records to a mature basis. The figures for the Holstein and Jersey breeds are arrived at from studies of the Advanced Registry records, while the figures for the other breeds are more or less arbitrarily arrived at.

AGE CORRECTION FACTORS USED BY VARIOUS BREED ASSOCIATIONS IN COMPUTING IMMATURE RECORDS TO THE MATURE EQUIVALENT

Age at Calving		Holstein	Jersey	Guernsey	Ayrshire
Years	Months				
Under 2 yrs.		1.50	1.45		
2	0	1.43	1.36	1.249	1.33
2	6	1.33	1.28	1.194	
3	0	1.25	1.20	1.162	1.22
3	6	1.19	1.14	1.100	
4	0	1.14	1.08	1.068	1.12
4	6	1.10	1.04	1.029	
5	0	1.06	1.02	1.00	1.00
5	6	1.04			
6	0	1.03	1.00		
6	6	1.02	1.00		
7	0	1.01	1.00		
7–6 to	9.6	1.00	1.00		
10		1.01	1.02		
11		1.03	1.02		
12 and over		1.05	1.05		

Relation of size and production. A number of students have shown that a direct relationship exists between the milk and fat yields and the size of the cow. Turner [1] reports an increase of 20 pounds of butterfat annually for each 100 pounds increase in body weight. A study of 220,000 records by the Bureau of Dairying [2] reveals a correlation of size with increased milk and fat yields, and also a larger income above feed cost. Gaines [3] recently showed that on the average the larger cows, while producing more than the smaller ones, are less efficient. It is apparent that size is not the most important consideration for economical production.

EFFECT OF SEASONS

Seasonal variations.[4] For a long time it has been recognized that there is a seasonal effect upon both the quantity and quality of cows' milk. Fat percentage is the lowest beginning with August; from this time there is an increase until January, when again there is a gradual decline until August. The amount of milk declines from the high point in January to the low of July and August. The seasonal variation in both milk and fat

[1] TURNER. Mo. Agr. Expt. Sta. Res. Bul. 147. 1930.
[2] McDOWELL. U. S. Dept. Agr. Circ. 114. 1930.
[3] GAINES. Jour. Dairy Sci. 14:14. 1931.
[4] WEAVER AND MATHEWS. Ia. Agr. Expt. Sta. Res. Bul. 107. 1928.
BECKER AND ARNOLD. Jour. Dairy Sci. 18: 389. 1935.

percentage is inversely proportional to the temperature. Several studies have shown that temperature variations may effect a greater variation in the fat percentage of milk than advancing lactation. For Jerseys and Guernseys the fat per cent of milk may be as much as 1.1 lower in the hot summer than in the winter. For the lower testing breeds the difference is 0.6.

When the temperature becomes too high, the amount of milk is reduced more than the amount of fat, resulting in an increased fat percentage. Cows kept at 85° F. or over in a closed room at the California Station [1] reached what is known as the critical temperature, when the above phenomenon was observed.

High humidity accompanied by high temperatures accentuates the depressing effects. With increasing humidity there is a decrease in the evaporation from the body, and thus the cooling effect of evaporating moisture is lost. That a much higher temperature in the open than 85° F. does not effect an increase in fat percentage is due to the cooling effect evaporation of moisture has upon the body.

Season of calving. As there is a seasonal effect upon both the quantity and quality of milk produced, the total milk and fat production for a lactation period is affected by the season in which a cow calves.

McDowell [2] divided the records of 10,870 cows into four groups corresponding to the seasons in which they freshened and found the following average productions:

Season	Milk Production	Butterfat Production
	Pounds	*Pounds*
Spring	5,842	236
Summer	5,941	236
Fall	6,689	268
Winter	6,439	258

Cows calving in the fall produced the most milk and butterfat, those calving in the winter ranked second. Owing to the lower fat percentage of milk during the summer, although the cows calving during the summer months produced slightly more milk than those calving during the spring, there was no increase in butterfat.

There are two reasons for the higher production of milk and butterfat of fall and winter calving:[3] First, the seasonal effect on fat percentage is such that the height of the milk production due to fall and winter calving will have the higher tests. Second, cows freshening in the fall and winter will still have sufficient capacity for milk production to respond by increased production when put on the spring pastures, while cows calving

[1] Regan, Richardson, and Kleiver. Abrt. of Papers 29th Ann. Mtg. Am. Dairy Sci. Assn. 1934.
[2] McDowell. U. S. Dept. Agr. Farmers' Bul. 1604.
[3] Cannon. Jour. Dairy Sci. 16:11. 1933.

in the spring and summer are so advanced in lactation that they have lost most of the capacity for increased production and cannot respond to the stimulus of fresh pasture.

FEED

The effect of inanition. Inanition or underfeeding has been shown to have a marked effect upon both the quantity and the quality of milk produced.[1] The most marked effect of inanition is the decline in the amount of milk produced. This decline continues as the period of inanition progresses. Accompanying the decline of milk yields are increases in the percentages of fat, protein, ash, and total solids. The percentage of lactose and the specific gravity decrease. When the lactometer reading is the only test performed, the decrease in specific gravity leads to the suspicion that the milk has been watered.

Effects of feed. Both the quantity and quality of milk may be affected by the feed a cow receives. Until recently it has not been generally agreed upon that feed affects the quality of milk to any great extent; recent work, however, tends to show that there may be marked effects of some feeds upon the composition of milk. In addition to affecting the quantity of milk, the feed may affect the fat percentage and the character of the fat, and it may add compounds to the milk or fat which may affect both its nutrient value and its flavor. The effect of liberal feed upon the quantity of milk produced will be discussed in Chapter 41.

Effects of feed upon milk fat. It is still controversial as to whether it is possible to increase the fat percentage of milk by feeding. Several short-time experiments have shown that the addition to the ration of fats such as linseed oil, cottonseed oil, tallow, butterfat, lard, soybean oil, coconut oil, and others causes a marked increase in the fat percentage of the milk.[2] Others,[3] comparing high fat content feeds with low fat feeds for the entire lactation period, were not able to observe any differences in the fat percentage of the milk that could be ascribed to the fat intake.

Feeding cod-liver oil to milking cows has been shown by a number of investigators to cause a marked lowering of the fat percentage of the milk without affecting the amounts of the milk yield.[4] This is said to be due to the specific effect some of the fatty acids of the oil have upon the epithelial cells of the mammary gland. Other fish oils are reported to have the same effect as cod-liver oil.

A minimum amount of fat in the ration seems necessary for milk production. A diet devoid of fat but adequate in all other respects resulted in much lowered milk and fat yields. The exact minimum level of fat in the ration that is necessary for normal milk production has not been established.

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[1] Overman and Wright. Jour. Agr. Res. 35:637. 1927.
Gowen and Tobey. Jour. Gen. Physiol. 15:45. 1931.
[2] Allen. Jour. Dairy Sci. 17:379. 1934.
[3] Maynard and McCay. Cornell Agr. Expt. Sta. Bul. 593. 1937.
[4] Petersen. Jour. Dairy Sci. 15:283. 1932.
Hart. Certified Milk. Sept., 1931.

Effect upon the quality of fat. Numerous experiments have been conducted to ascertain the effect of various feeds upon the quality of the milk fat. It has been demonstrated that the composition of milk fat can be markedly changed by a number of different types of feed. In the main, the fatty portion of the feed is responsible for the effect upon the composition of the milk fat. Cottonseed oil produces a very hard fat, while linseed oil produces a soft fat. Linseed oil, having a high linoleic and linolinic acid content, produces butter with relatively high amounts of these two fatty acids, which are mainly responsible for the softened condition of the butter produced when flax, oil meal, and the oil is fed. Due to an increase of the lower fatty acids, such as butyric, caproic, and caprylic acids, pasture grass produces soft butter. The hays and legumes, being as a rule low in their contents of fats, have a tendency to produce hard butterfat. Corn has a tendency to produce fat of a moderate hardness, while barley and other cereals are more neutral in their effects upon the milk fat.

Effect of feed upon other milk constituents. No evidence has been presented that has shown feed to have any effect upon the lactose or protein content of milk. There is, however, some evidence to show that the amount of certain other constituents of milk is dependent upon the extent that these are present in the feed; among these are vitamins A, D, and E, certain flavoring compounds, mineral elements, drugs, and other organic compounds.

Vitamins. Vitamins C[1] (ascorbic acid) and at least B and flavin of the Vitamin B complex may be synthesized in the bovine; and as a result these vitamins are always present in milk and vary but little due to variations in the feed. Vitamins A, and D, however, are not synthesized by the bovine, and the amounts present in the milk are dependent upon the amounts present in the feed, and, in the case of vitamin D, also upon exposure to sunlight.

Carotene, the chief plant precursor of vitamin A, is a yellow pigment which can be split in the animal body to form vitamin A, which is colorless. Cows may secrete the carotene into the milk, producing a yellow fat, or they may split the carotene and secrete the colorless vitamin A into the milk. Although there is no known difference between individual cows in utilizing the vitamin A of the feed for total vitamin A potency of the milk, there are marked individual and breed differences in the amounts of carotene converted into the colorless vitamin A.[2] The Guernsey is noted for the secretion of the carotene into the milk; the Holstein converts most of the carotene into the colorless vitamin A; and the Jersey is intermediate. Sometimes feeds are so deficient in vitamin A or vitamin A precursors that the milk produced is deficient in vitamin A to the extent that calves cannot be raised upon it. Matured timothy hay has been shown to produce milk upon which calves could not be reared because of its deficiency in vitamin A.

[1] Hughes, Fitch, Cave, and Riddell. Jour. Biol. Chem. 71:309. 1927.
[2] Russell, Taylor, Chichester, and Wilson. N. J. Agr. Expt. Sta. Bul. 592. 1935. Kraus and Washburn. Jour. Dairy Sci. 19:454. 1936 (Abstn.).

Vitamin D is present in milk proportionately to the amounts fed in the feed, except when the cows are exposed to direct sunlight during the spring, summer, and early fall, when vitamin D may be formed in the animal body from the ultraviolet rays of the sun. Commercially, the production of vitamin D milk during the winter is affected by the feeding of irradiated yeast.

Minerals. The amounts of the most prominent minerals in milk, the salts of phosphorus, calcium, magnesium, sodium, potassium, and chlorine, cannot be changed by the amounts in the feed. Copper, silver, and zinc, which are always present in milk in very minute quantities, are likewise unaffected by the quantity in the feed. Iodine and iron are the only two natural mineral constituents of milk the amounts of which are influenced by the quantity in the feed. Of these iodine may be influenced to the greater extent and iron but slightly. The ingestion of iodine in any form will increase the iodine content of milk. In the low iodine regions some dairymen feed iodine in various forms in order to increase the iodine content of the milk produced. From 3 to 20 per cent of the iodine ingested may be recovered in the milk—more of a recovery taking place during the winter than during the summer. To increase the iron content of milk, large quantities of inorganic iron must be fed; and then the increased amount in the milk is small.

Arsenic, mercury, lead, bromine, and boric acid, not normally present in milk, when fed, will pass into the milk. When heavy doses are administered, sufficient quantities of these elements may pass into the milk to make the milk toxic to humans.

Drugs passing into milk.[1] There are a number of drugs and anesthetics used in the treatment of cows that will pass into the milk. Alcohol may be found in the milk 30 minutes after its administration, and disappears in four to seven hours. As much as 0.4 per cent of alcohol in milk has been reported. Ether and chloroform behave similarly to alcohol, as does turpentine. The active substance of rhubarb passes into milk to produce a yellow coloring of the milk. The active substance of aloes (a bitter plant) passes into the milk in such quantities as to alter both the color and the taste.

The white snakeroot contains a poisonous compound known as tremotol which passes into the milk.[2] Ordinarily cows do not eat the white snakeroot, but in cases of severe drought and feed shortage, cows have eaten it in sufficient quantities to make the milk toxic to humans, producing what is known as milk sickness. Milk sickness has proved fatal in a few cases.

Flavor-producing constituents of feed. Most of the normal flavoring constituents of milk have their origin in the feed. There are, however, many feeds that produce very undesirable milk or milk fat flavors. Among the more common feeds that impart undesirable flavors to milk, if fed

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[1] KOLDA. Le Lait 6:12. 1926.
[2] COUCH. Jour. Agr. Res. 35:547. 1927.

shortly before milking, are silage, large amounts of alfalfa hay, turnips, rutabagas, rape, cabbage, green rye, and pasture grasses.

Many weeds consumed when pasture grasses become scarce or because they are admixed with the grasses produce undesirable flavors of varying intensities. The more common of the undesirable flavor-producing weeds are wild onions, French weed, ragweed, mustard, sagebrush, and dandelions.

Of the essences, absinthe, fennel, and artichoke produce strong flavors in milk. The oral administration of cumin, anise, gentian, and juniper has no effect upon the flavor of milk produced.

In the main, the compounds producing off flavors in milk are volatile and may be removed from the milk by feeding the flavor-producing feeds immediately after milking or by removing the cows from the feed for varying lengths of time before milking. These compounds are eliminated from the blood by either the lungs or kidneys, or both. They pass into the milk from the blood, forming an equilibrium between these two fluids. As the quantities of the compound are reduced in the blood through elimination, these compounds pass from the milk back into the blood until finally the milk is entirely freed of them.

Effect of drugs upon the amount of milk secreted. A number of drugs have been studied for their stimulating effect upon milk secretion. While the results of the different workers do not agree, in the main, very few, if any, compounds are known to have galactogogic effects. Alcohol, ginger, rhubarb, aloes, pituitrin, pilocarpine, calomel, atropine, and a number of other drugs have been shown to have no galactogogic effects. Pituritrin administered subcutaneously or intravenously causes an increase in the amount of milk and milk fat produced at the following milking. This is due to the contractile effect of the pituitrin upon the glands, which results in the forcing out of all the milk and fat in the alveoli, and not to any stimulus for increased secretion of milk. The active principle of ergot causes a marked decrease in the amount of milk produced, probably due to the constricting action of ergot upon the blood capillaries. Pumpkin seeds, hedge oranges, acorns, and oak leaves have been reported by dairymen to cause a drying up of cows. There is, however, no experimental evidence to support this contention.

Thyroprotein. Thyroprotein is a term applied to proteins, usually casein, so treated with iodine that they develop thyroid hormone activity. When fed to milking cows both milk and fat percentage will be increased. A sufficient amount of the thryoprotein must be administered or no effect will be observed. Small amounts will depress the thyroid activity in proportion to the amounts that get into the system. About 15 grams of the standard thyroprotein must be administered daily, usually incorporated in the feed.

The question as to the practicability of feeding thyroprotein is not settled. While milk and fat production is significantly increased, the feed requirements are also greatly increased because of the greatly increased activity in metabolism. Heart and respiration rates are greatly increased

and questions are raised as to the effect upon the health of the animals and upon reproduction. Indications are that good milkers past the peak of the lactation respond best to the administration of this drug and that poor producers give the least response.

EFFECT OF DISEASE

Udder diseases (principally mastitis), digestive disturbances, and other diseases are responsible for a decrease in milk yield and affect the quality of the milk in various ways.

Mastitis. The composition of the milk may be changed in various degrees by mastitis infection, depending upon the severity of the infection. The reduction in milk of the affected quarter is likewise dependent upon the severity of the attack. The sugar content decreases from a very slight amount in a light attack to practically nothing in a very severe attack. Sodium chloride increases until it approximates the concentration in the blood. The character of the proteins changes with a decrease in casein and an increase in the heat coagulable proteins. The *p*H changes from approximately 6.5 to 7.4 in the extreme case, and the cellular materials, principally leucocytes, increase from a few thousand in normal milk to millions per cc. in extreme mastitis milk. The fat content usually declines.

Digestive disturbances. Any marked digestive disturbance, such as going "off feed" or diarrhea, is followed by a marked decline in milk yield. The fat percentage of the milk usually increases, but in some cases it may decline. The flavor of the milk is also usually affected; putrefactive decomposition compounds are resorbed from the digestive tract by the blood and are diffused into the milk.

Other diseases. Any disease which is severe enough to produce an increase in the body temperature or to reduce the appetite for feed is accompanied by a decline in milk yield. Usually the fat percentage of the milk increases, but sometimes the reverse may be the case.

Practical aspects of feed effects upon milk. The deleterious effects of many feeds upon flavor of milk is well known, and dairymen refrain from using such feeds or feed them immediately after milking or allow sufficient time between feeding and milking for the undesirable flavor to have passed off. That there are substances that may be fed to produce desired flavors in milk seems most likely. Determining such substances seems to offer a fruitful field in research. It is also possible that certain food substances may be found that may counteract the undesirable milk flavors produced by some feeds.

Chapter 34

MANAGEMENT OF DAIRY COWS

IMPORTANCE. EVERYTHING THAT PERTAINS TO THE FEEDING, CARE, AND breeding of dairy cattle can properly be classified as coming under the term "management." It has previously been pointed out that for a cow to be an economical producer of milk, she must have the right inheritance; however, given a cow with the inheritance for the capacity to produce large amounts of milk, economical production is not necessarily assured. The cow must be properly fed and cared for in order to bring out the potentialities that she has inherited. It is the purpose of this chapter to consider the more important managerial factors that relate to bringing out the inherited potentialities for milk production.

Normal physical and physiological activities. A knowledge of the normal activities of dairy cattle is of value in the management of the herd, and it may aid in arranging work to fit the activities of the cow and help to determine whether a cow is normal. The amount of information available on this subject is limited, the New Hampshire Station [1] furnishing the most extended work on dairy cows. They report that cows in the barn during winter spend about equal amounts of time in standing and in lying down; there is, however, a tendency for cows in advanced pregnancy to spend more time in lying down than in standing. Individual variations ran from as high as 76 per cent to as low as 35 per cent of the time spent in standing. Cows got up and down on an average of 14 times during the 24 hours.

Variations in the number of urinations and defecations per day between dry cows and milking cows were observed. Dry cows average 6.1 urinations to 7.9 for milking cows. For daily defecations, dry cows averaged 13.7 times as compared with 15.7 for cows in milk.

No difference was found between dry cows and those in milk as to the amount of time spent in eating and in ruminating. Cows fed hay, silage, and grain in proportion to milk yields spent approximately three hours in eating and eight hours in ruminating. Since roughage consumption is proportional to the size of the cow and grain consumption is proportional to the amount of milk produced, and since it requires longer to eat a given weight of roughage than of grain and grain is not ruminated, the reason for high producing cows requiring no more time for eating and rumination than dry cows do is easily perceived.

The large amount of work done by a cow in eating and masticating feed is indicated by the average daily number of jaw movements:

[1] FULLER. N. H. Agr. Expt. Sta. Tech. Bul. 35. 1928.

Eating grain and silage	4,700
Eating hay	10,530
Ruminating	26,400
Total daily jaw movement	41,630

A difference was observed in the number of jaw movements per minute when hay, grain, and silage were eaten. A still different rate was observed for ruminating. The average jaw movements per minute for hay are 78, for grain and silage 94, and for ruminating 55.

Great variations are found in the pulse and respiration rates. Judkins observed the average pulse and respiration rates for different breeds to be as follows:

Breed	Rate per Minute		Ratio
	Pulse	Respiration	R to P
Ayrshire	69.6	28.6	1 : 2.4
Guernsey	59.8	18.6	1 : 3.2
Holstein	68.6	28.6	1 : 2.8
Jersey	62.7	21.7	1 : 3.2

The respiration rates varied from 11 to 64 per minute, and the pulse rates from 38 to 96 per minute. Both pulse and respiration rates increased when cows were milking heavily.

The behavior of the cow. Ever since dairying became a specialty people have recognized that some individuals are able to obtain better performance from cows than others. More recent work has shown that cows that are well adjusted to their environment will let down their milk more completely and probably also will eat better than those that are not so adjusted. One of the major jobs of the dairy herd manager is to see that the members of the herd are content and well adjusted. In order to attain this end most effectively one needs to know some of the fundamentals about the pattern of behavior of the cow. The two basic features are: (1) cows have a well-established herd order and (2) they are quick to make associations of pleasant or unpleasant experiences with places, objects, and persons.

Herd rule. In every herd there is a well-established social order in which there is one cow that rules over all the rest, followed successively by the other members of the herd with the last cow in the social order being bossed by all the others. The position in the social order is established by physical combat. Once a cow has succeeded to the top position she retains it for life unless an ambitious individual is brought into the herd from the outside. The younger members developing in a herd accept the supremacy of the leader of that herd. Studies by the author reveal that sometimes members in the middle of the social order of larger herds may be unhappy. They manifest their discontentment by irritating members in the lower

social order. It is presumed that these unhappy individuals are aggressive and aspire to a higher rank but do not possess the physical strength to gain it and, consequently, suffer from frustration. These individuals, incidentally, are the more difficult to handle from the managerial standpoint.

Associations. The fact that cows readily make associations with pleasant and unpleasant experiences in relation to the human element is very important from the caretakers and particularly the milkers relationship. Often veterinarians are forced to inflict pain in carrying on their work with cattle. One such experience is sufficient for the animal to associate that painful experience with the veterinarian and his subsequent presence will cause nervousness and excitement. Milk production has been noted to fall markedly due to the presence of the herd veterinarian at milking time.

It is of utmost importance that the caretaker of cows so handle them that they like his presence. Only when there are pleasant associations will cows be relaxed and at ease in the presence of particular individuals. Where cattle are well treated by all humans they like their presence and even in the case of strangers show no fears. In the case of unkind treatment cows will make effort to escape or at least will not be approachable by strangers.

Regularity. While there is no definite experimental evidence to establish the value of regularity in milking, feeding, and caring for the dairy cow, there is enough evidence to warrant the statement that regularity is an important factor in getting the most out of the dairy herd. It has previously been shown that lengthening the periods between milking increases the milk production, but that the increase is not in proportion to the length of the interval. The cow is a creature of habit. If the time for milking or feeding is delayed, she is likely to become nervously excited, and this results in reduced milk production. A definite routine in milking, feeding, and caring for cows should be established. If the cow is to be fed before milking, the practice should be followed regularly. It has frequently been observed that if a cow which has been accustomed to being fed before milking is milked before feeding, she fails to completely let down the milk.

Quietness. The chasing of cows by dogs so excites the cows that decreased milk production results. Even the presence of too many people will result in decreased production. For this reason experienced herdsmen in charge of cows on official tests, where a maximum production is sought regardless of cost, sometimes lock the barn in the interim between milkings to prevent anyone from disturbing the cows. Under these conditions the visits of strangers are seldom permitted, because of the probable effect on production.

CARE OF HEALTH AND APPEARANCE

Grooming. Grooming has usually been considered as having a beneficial effect upon the general health of the cow, an effect which would be reflected in increased production. Recently carefully controlled experiments failed to reveal any increased production of milking cows due to

vigorous grooming with a stiff brush.[1] The chief advantage of grooming is that dirt is removed from the skin and hair—not that production is increased. Most benefits from grooming will come in the production of cleaner milk.

Exercise. It is usually believed that exercise is essential for the health of dairy cattle. Recently it has been found that exercise is not essential for the health of milking cows. Cows maintained in stanchions or box stalls have been found to have suffered no ill effects from the confinement. The milking cow performs a large amount of work in the mastication and metabolization of the feed that she necessarily must handle; this activity seems to furnish adequate exercise. Young stock and dry cows, on the other hand, seem to be benefited more by moderate exercise. In the colder climates letting the milking cows out into a yard for exercise during the winter probably does more harm than good.

Trimming hoofs. When cows are confined to barns during the winter months and when they are pastured on soils that are lacking in abrasive material, the hoofs grow faster than they are worn off, resulting in the development of long toes that ultimately produce discomfort to the cow both in standing and in walking. In extreme cases lameness leading to a crippled condition may be experienced. The hoofs should be trimmed by chiseling off the fore part of the toe and rasping off the excessive growth underneath. Extreme care must be exercised in the trimming to avoid injury to the quick. Injury to this tissue may lead to infection and lameness of long duration.

Training horns. For some breeds when animals are to be shown, it is not only essential that the horns be retained, but also that they conform to the standards for the breed. Frequently the direction of the natural growth of the horn is not that which is most desired. It is then necessary to force the horn to grow in the desired direction. The time when the direction of the growth can most easily be changed is before the horn core is securely fastened to the skull. Therefore, the training of horns should begin about the time they are two inches in length.

The direction of the growth of a horn may be changed by the application of pressure. If the horn tends to grow upward, the direction may be changed downward by fastening weights to the horn tips until the growth is in the desired direction. If the horns have a tendency to grow outward when it is desired that they should curve inward, the desired curvature may be effected by applying tension between the two horns by means of horn trainers fastened to the horn tips. Care should be taken not to put too much tension on the horns, as it will produce not only discomfort to the animal but also too abrupt curvature of the horns. In the case of the Ayrshire it is desirable that the horn turn upward. This may be effected by directing the force upward by means of weights hung on cords that have been attached to the horns and then run over pulleys.

[1] White. Conn. (Storrs) Agr. Expt. Sta. Bul. 181.

The direction of the growth of the horn may also be changed by scraping it on the side toward which the direction of growth is desired.

Horns are frequently too large and thereby detract from the general refined appearance of the animal. In order to correct this, they may be trimmed by rasping off a portion of the outer covering known as the horn shell. Care should be taken not to take too much off or the outer shell may become so weakened that it will break off from the bony horn core. Frequently animals that have been shorn lose the outer horn shell because of its weakened condition from excessive rasping or scraping. Following the rasping, the horn should be sandpapered with fine sandpaper or emery cloth until a smooth surface is secured. Then a horn polish may be applied and the horn polished with a cloth. For show purposes the hoofs may be trimmed and polished in a similar manner.

Dehorning.[1] It is generally agreed that unless it is necessary to retain the horns on dairy cattle for show ring purposes or for the probable enhancement of the value of an animal when it is sold, it is desirable to dehorn the cows. In herds where animals are horned, injuries are often experienced. In addition, the more timid individuals of the herd are constantly harassed by the more aggressive members. The best method of dehorning is the application of caustic potash when the animal is but two or three days of age. However, horns may be removed from older animals without much danger and with practically no effect upon the milk yields of even heavy producing cows. A number of observations have shown that milking cows drop in milk yield for but a few days following dehorning. Horns may be removed either by the use of clippers or by sawing. Sawing is generally to be preferred, for when clippers are used there is the danger of crushing the bony horn core, which may result in excessive bleeding or infection. In dehorning, care should be taken to cut the horn low enough to leave a fringe of hair and skin on the removed portion of the horn. Unless this is done, the horn is likely to grow out again. The early spring is the best time for dehorning. It should not be done during fly season, because of the danger of infection resulting from flies settling on the injured area. Also, when the cattle have been fed sweet clover either as hay or silage, dehorning should be avoided. Frequently the sweet clover hay or silage develops a substance which prevents clotting of the blood, and if the animals are then dehorned, they may bleed to death.

TREATMENT OF COMMON VICES

Cows may develop several vices that are annoying. The more common ones are kicking during milking, sucking either themselves or other cows, fence breaking, and becoming vicious. Most of these vices can be avoided if the tendency is discovered in time and proper treatment applied. After any one of these has become a habit, it becomes exceedingly hard, if not impossible, to break.

[1] U. S. Dept. Agr. Farmers' Bul. 949.

Kicking. The habit of kicking during milking is most frequently developed as the result of wrong treatment when the heifer is first milked. At first the cow kicks either because of pair or fear. If she is maltreated at this time, kicking becomes an act of resentment and rapidly develops into a habit that cannot be broken. Frequently cows kick only when milked by certain milkers. When kicking during milking has been established as a firm habit, there is nothing that can be done to break it. The treatment then lies in tying the hind legs in order to protect the milker. The most effective and convenient method is the use of antikicking chains. These consist of two hooklike pieces of iron connected with a chain. A hook is placed above each hock with the chain passing in front of the legs. When the chains are not available, the hind legs may be tied together either with straps or with rope.

Sucking. The habit of sucking is also practically impossible to break. Cows have been tied up in stanchions for more than a year without any chance of sucking either themselves or other cows without being broken of the habit. The treatment lies in methods of prevention. The sucking cow may be prevented from sucking by the use of anyone of three contrivances: (1) a contrivance such as a chain or two bull rings placed in the nose in such a way that it hangs over the muzzle, preventing her from getting hold of the teat; (2) a bridle equipped with a quarter-inch gas pipe drilled full of holes used as a bit, which does not permit sucking; (3) a halter with a muzzle strap containing sharp points that are two or more inches in length. The self-sucking cow may be prevented from sucking by making it impossible for her to turn her head back to the rear flank. This may be accomplished by fixing a surcingle around her chest, fastening one end of a short stick to the surcingle, and then passing the stick between the front legs and fastening the other end of it to a close fitting halter. Although not proved, some believe that feeding skim milk to cows is conducive to forming the sucking habit.

Fence breaking. The habit of fence breaking or fence crawling is usually developed when cows are kept within poor fences. When once developed, this habit can be broken only by the use of good fencing. A cow may be prevented from crawling through fences by a yoke placed around the neck. Fence breakers frequently teach other cows in the herd the same habit. For this reason it is advisable to dispose of them unless they are valuable producers.

Viciousness. Not infrequently cows become vicious to the extent that they will attack children and sometimes adults. In the early stages of the development of this habit it may sometimes be broken by a few sharp blows over the nose. This is more effective if done by the person attacked at the time of the attack.

CARE IN BREEDING AND CALVING

Gestation period and estrus cycle. The average gestation period for the cow is 281 days, with about equal chances of calving on any day from the 275th to 287th day. There is a question as to how many days

short of the 281 that a calving can be considered normal, and when it should be considered an abortion. Gestation periods as long as 300 days have been reported.

The normal estrus cycle in the cow is 21 days. Variations of five days from the average is not uncommon. The first oestrus cycle usually occurs one week following calving. Disease and malnutrition may be the causes of complete suppression of the oestrum. In extreme nutritional deficiency such as a lack of phosphorus or a vitamin deficiency, oestrum does not occur until the deficiency is corrected and the body stores recuperated.

When to breed cows. According to the data presented in the preceding chapter, breeding a cow so as to conceive on the 75th to the 110th day following calving results in the greatest average daily milk production for the lactation period. Breeding on the 85th day results in calvings 12 months apart. Breeding earlier than the 75th day results in a greater reduction of milk yield than in the time between calvings. Breeding for conception on the 30th day following calving causes a reduction in the milk yield of 18.4 per cent for heifers and 21.3 per cent for older cows, while the time is shortened by only 15.1 per cent. When more than 110 days intervene between calving and conception, the per cent increase in the length of time between calvings becomes greater than the increased milk yield, resulting in lower average daily yields.

Relation of the Number of Service Periods to Conception[1]

Number of Service	Number of Cows	Number of Conceptions	Percentage of Conceptions	Chance of Conceptions
First	1,280	547	42.7	1 : 2.3
Second	729	258	35.3	1 : 2.8
Third	466	146	31.3	1 : 3.2
Fourth	306	79	25.8	1 : 3.9
Fifth	210	55	26.1	1 : 3.8
Sixth	142	29	20.4	1 : 4.9
Seventh	104	17	15.8	1 : 6.1
Eighth	78	9	12.0	1 : 8.7
Ninth	63	6	9.5	1 : 10.5
Tenth	52	4	8.0	1 : 13.0
Eleventh to twentieth	168	4	2.3	1 : 42.0
Twentieth to fortieth	100	0	0	0

By breeding cows on the first heat period following the 75th day after calving it is possible to secure pregnancies for all but a small per cent of a normal breeding herd by the 110th day following calving.

Breeding efficiency. The number of services required per pregnancy is partly dependent upon the amount of sterility present in the herd, and for any one herd it would vary considerably from year to year. The data presented in the previous table, secured from the University of Minnesota herd over a period of 29 years, is probably representative of what may

[1] Eckles. Minn. Agr. Expt. Sta. Bul. 258.

be expected in a herd over a period of years. It will be noted that there is one chance out of 2.3 that conception will occur to the first service. With each additional service, the chance of conception becomes less.

Sterility. One of the very serious problems that a breeder encounters in building up a herd is that of sterility. The percentage of sterility for each age group as observed in the University of Minnesota dairy herd over a period of 29 years is shown by the following table. It will be noted

RELATION OF AGE AND STERILITY IN DAIRY COWS [1]

Age Years	Total Cows	Number Sterile	Per Cent Sterile	Ratio of Sterile to Total
2	311	23	7.4	1 : 14
3	217	8	3.6	1 : 28
4	139	5	2.8	1 : 36
5	127	8	6.3	1 : 16
6	87	5	5.7	1 : 18
7	69	3	4.3	1 : 23
8	56	2	3.6	1 : 28
9	51	4	7.8	1 : 13
10	41	2	5.0	1 : 20
11	34	4	11.7	1 : 9
12	25	3	12.0	1 : 9
13	19	4	21.0	1 : 5
14	12	2	17.0	1 : 6
15	9	3	33.3	1 : 3
16	5	1	20.0	1 : 5
17	2	1	50.0	1 : 1

that the highest proportion of sterility up to nine years of age occurs in the two year old group. After ten years of age, the percentage of sterility increases rapidly with increate in age.

While not all the causes of sterility are known, a number of factors are known to cause or contribute to sterility either temporarily or permanently. Heredity is undoubtedly one of the major factors contributing to the sterility of the two year old group, and it is not inconceivable that sometimes temporary sterility may be due to hereditary factors. From the preceding table, it is seen that age is a factor. Nutrition is also a factor. Badly undernourished cows do not come into estrus. Animals on a phosphorus deficient ration frequently do not show normal oestrus until the phosphorus level of the body has been restored.

The part that nutrition plays in sterility is not fully understood. Cows in severe inanition states do not show estrus and, whether or not there is ovulation, from a practical standpoint breeding efficiency is impaired. Phosphorus deficient cows may ovulate with regularity yet estrus is absent and practical sterility results. Vitamin E has been shown not to be a factor in bovine fertility as rations free of vitamin E showed no impairment of estrus or lowered conception rates.

[1] *Ibid.*

One of the major causes of sterility is diseases of the reproductive tract. Brucellosis, trichomoniasis, accidents to the genital tract during parturition and many other disease factors are responsible for much temporary and permanent sterility.

The rest period. It has previously been shown that by giving a cow a rest period lactation will be increased in the following lactation period.[1] There are probably two reasons why a rest period results in greater production during the subsequent lactation period. The more important is undoubtedly the building up of body reserve to be used in the production of milk following calving. The other reason is the effect of the rest period upon the recuperation of the mammary gland tissue.

The manager of a dairy herd is confronted with the problem of deciding the length of the rest period that will give the best results. The objectives may be either to have the cow produce the largest amount of milk regardless of cost or to produce economically. The data given by Sanders, presented in the table on page 342, showed that up to a certain rest period, of at least 115 days, there is an increase in total production for each increment in the length of the rest period. Therefore, in order to prepare a cow for maximum production regardless of cost, the longer the rest period the greater the production that can be expected.

For the most economical production other factors than those that affect maximum production must be considered. While the production of the subsequent lactation period continues to increase with the increases in length of the dry period, the rate of increase decreases with each successive lengthening of the dry period. This, with the fact that lengthening the dry period shortens the current lactation period, makes it obvious that there is a limit to the length of a dry period that will be the most economical. A difference is noted for heifers and older cows in the effect of the length of the dry period upon subsequent production. It is apparent that longer dry periods are to be advised for heifers than for older cows; this is due, no doubt, to the need for further growth and development of the heifers. According to the data given by Sanders, a dry period of 45 days for heifers increased the subsequent production by 33.2 per cent, while for older cows an increase of only 18.5 per cent was experienced over no dry period. For 115-day dry periods the respective increases over no dry period were 52.2 per cent and 30.2 per cent. With a 45-day dry period as the base, an extension of 75 days increased the production 8.1 per cent for heifers and 3.8 per cent for cows. Extending the dry period to 115 days increased production 14.2 per cent and 6.0 per cent respectively.

Under average conditions optimum results are secured with a dry period of 40 to 45 days for older cows and 70 to 75 days for younger cows. There are, however, conditions which will alter the length of the dry period. Cows in poor condition need longer dry periods for building up the necessary body stores, and underdeveloped heifers need more than the normal length of dry periods for the needed additional growth and development.

[1] Chapter 33.

Care of the dry cow. Since the main object of the dry period, aside from the possible recuperative effect upon the mammary gland, is to build up body reserve for the next lactation period, the cow should be fed liberally with well selected feeds. As the body stores are made up mainly of fat and mineral matter and contain only relatively small amounts of protein, the feeds furnished during the dry period should supply adequate minerals and energy with enough protein to satisfy the maintenance requirements. The guide to a satisfactory ration will be the condition of the cow. If an excellent quality of legume hay is fed, it alone may be adequate provided the cow is in fair condition at the beginning. Good pasture is always adequate. When the cow is in poor condition to begin with, it is essential to feed some concentrate. The cheapest concentrate, selected on an energy basis, is the one to be chosen. If the cow is in very poor condition, six to eight pounds of concentrate may be fed daily. In localities where the soil is deficient in phosphorus or where a poor grade of nonlegume hay is fed, bone meal should be furnished as a source of calcium and phosphorus.

During the winter in colder climates, except for the severest days, the dry cow should be let out daily for exercise. During the warmer months she may be left in the pasture continuously. While mechanical abortions are comparatively infrequent in cattle, the cow in advanced pregnancy should not be chased by dogs, hurried on ice or slippery pavements, or handled roughly.

Care at calving. The welfare of both the cow and the calf is frequently dependent upon the care given during calving time. Neglect and improper attention at this time may result in the loss of both the cow and the calf, or may cause a weakened condition of both that results in the ultimate loss of the calf and decreased milk production for the cow. The cow is subject to several hazards at this time, including difficult calving, congestion of the udder, retained afterbirth, digestive disturbances, and milk fever, any of which may result in disaster and which may be avoided by careful attention.

The approach of calving is ascertained from the breeding date and the appearance of the cow. As calving time nears, the external genitalia become enlarged, the ligaments on either side of the tail head become relaxed and sunken, and the udder becomes more congested. When these signs are observed, the cow should be carefully watched. She should be placed in a maternity pen in the barn or in a small clean pasture lot if the weather is favorable. The maternity pen should be disinfected with lysol solution and bedded with clean straw or shavings. A laxative feed should be fed; three or four pounds of a mixture of bran, ground oats, and linseed oil meal is excellent. At the first signs of labor, the cow should be carefully watched for any needed assistance, but should not be disturbed, as any excitement interferes with the natural process. If no progress is made after two hours of labor, an examination should be made to determine whether the calf is in normal presentation of forefeet and head foremost. If the presentation is abnormal—that is, if other parts of the calf's body are fore-

most—assistance is needed, and a veterinarian should be called, as should be done for all other difficulties in calving.

The newborn calf sometimes has a membrane over the nostrils; this must be removed or suffocation will result. If the calf is of normal strength and the cow is normal, it is best to leave the cow and the calf alone in the box stall or small pasture lot. Only when the calf is weak or the cow shows inattention toward the calf should assistance be rendered. If the cow fails to lick the calf, it should be dried by vigorous rubbing with straw or cloth. When the calf is too weak to nurse, it should be assisted to secure colostrum milk as soon as possible after birth, preferably within one-half hour. Colostrum milk, in addition to furnishing food, is laxative and contains antibodies which make the calf more resistant to later infection.

Unless the cow is infected with some contagious disease, it is well to leave the calf with the cow for the first two or three days after calving.

Loss of weight due to calving.[1] If the cow has been properly fed, there is a progressive increase in body weight up to calving and then a sudden decline. The increase in weight during pregnancy is due to three factors: growth of the fetus and fetal membranes, body growth, and storage of mainly adipose tissue. The greatest increases in weight occur with the first calf heifers, with progressive decreases for each successive gestation until maturity. The decrease in weight at calving time is due to the loss of the calf, placenta, and amniotic fluid. After calving, there is a still further decrease in weight for an average of 45 days, due to insufficient feed intake to supply maintenance and milk production requirements. Milk is then produced in part from body stores.

Nebraska Station workers studied weight gains during pregnancy and losses due to calving for 656 gestations. They found weight losses varying from 78 to 151 pounds. For the first gestation the loss in weight represented 11.8 to 12.9 per cent of the cow's weight, while for older cows the loss varied from 8.1 to 12.0 per cent. The placenta and amniotic fluid weights varied greatly, the lowest being 22 pounds and the largest 58 pounds. In terms of body weight, this represented 1.9 to 5.1 per cent.

Feeding after calving. As soon after calving as the cow will drink, she should be supplied fresh water. It is desirable that the water be lukewarm; it is essential that ice cold water be warmed. As much hay as the cow will consume should be allowed, and the laxative grain mixture should be continued for at least two days. The amount of feed consumed for the first few days is not important; if the cow is in good condition when calving, the body reserve will supply the body needs. The important problem is to maintain a good condition of the digestive system by avoiding overfeeding. After the second or third day following calving, if normal progress has been made, the calf may be removed and the cow returned to the herd. The amounts of concentrate should then be gradually increased with the aim of reaching full feed in three weeks—except

[1] Morgan and Davis. Neb. Agr. Expt. Sta. Res. Bul. 82. 1936.

for very high producers, which may not reach full feed in less than six weeks' time.

Difficulties encountered following parturition. Following parturition, the cow is subject to a number of afflictions that, unless immediate and competent attention is given, may result in disaster. These afflictions may be divided into those that affect the generative organs and those concerned with the mammary glands.

Due to the strain of calving and the engorged condition of the genital tract, the vagina and uterus may become bruised or torn, leading to infection; this condition requires the attention of a veterinarian. These and other factors may be responsible for eversion of the uterus and retained afterbirth. In eversion of the uterus the organ fails to contract, inverts, and protrudes. By the skilled attention of a veterinarian, the uterus may be returned and held in place by appropriate means until it is completely contracted.

Retained afterbirth. Normally the afterbirth should come away within four to six hours following parturition. Following abortion, and for other reasons not known following apparently normal calving, the afterbirth fails to come away naturally. The afterbirth is attached to the uterus walls by from 50 to 100 cotyledons through which the nourishment passes from the blood to the fetus. Normally these attachments are such that they break from the uterine contractions following parturition, but sometimes they grow firmer and the afterbirth is not expelled.

If it is not normally expelled, the afterbirth may be removed by pinching off the attachment of the cotyledons. This should never be attempted by anyone except a skilled person. Unless carefully done, injury will be caused that will result in permanent sterility.

As soon as it becomes evident that the afterbirth will not be expelled naturally, it should be removed. Unless this is done decomposition sets in and the toxic decomposition products are absorbed into the system, causing loss of appetite and marked decline in both weight and milk yields. The decomposing retained afterbirth may also be a contributory factor to sterility.

Congested udder. High producing cows usually suffer from a congestion of the udder immediately following calving; this congestion lasts for varying lengths of time. In some cases the congestion may be due in part to an infection. In the majority of cases, however, it is a natural sequence to the rapid development of the gland and is caused by the accumulation of tissue fluid (or lymph) in the gland tissues.

The degree of congestion is influenced by a number of factors. Exposure to drafts and chills intensifies the congestion and may lead to infection (discussed under "Udder Diseases"). The higher producing cows are more subject to congestion of the udder than are lower producers. Cows in high condition also suffer from greater congestion than do those in poorer condition. The claim by some that certain feeds are specifically conducive to udder congestion is not warranted by fact.

In extreme cases of congestion milking becomes very difficult because

of the shortened teats and the slowness with which the milk is let down. When this is the case, it may be advisable to leave the calf with the cow until the congestion has somewhat receded. Some believe the massaging of the udder by the calf is helpful in reducing the congestion. Additional vigorous massaging by the hands will help to start the flow of the lymph out of the tissue and reduce the congestion.

As the result of several recent studies, prepartum milking has been demonstrated to be the most satisfactory solution of the congested udder problem. Milking should be started as soon as signs of congestion develop. With the beginning of milking not only is further progress of congestion stopped but the swelling that is present will gradually disappear. Work thus far indicates that prepartum milking will not depress milk flow following parturition. In prepartum milking there will be no colostrum following freshening and provisions for this substance for the newborn calf must be made in other ways. The first two or three milkings (prepartum) will result in normal colostrum, which may be preserved for the calf by freezing.

Prepartum milking not only prevents undue swelling of the udder and thus makes milking easier after calving, but also is a factor in preventing a breaking away of the udder. The excessive swellings that sometimes occur puts more weight and stress on the suspensory mechanism than it is able to withstand and a breakdown results. Mastitis may be lessened to some extent by prepartum milking because the excessively large swollen udder is more subject to injury and thus predisposed to infection.

Milk fever or parturient paresis. Milk fever is a disease usually limited to high producing cows. While it may occur at any time during the lactation period it rarely occurs except following calving. The first symptom of this disease is staggering, with particular lack of control of the hind legs. The disease advances with progressive increases in paralysis and ends in prostration and complete coma; and unless relief is administered, it terminates in death. When complete coma has appeared, the cow lies with her head turned back against her chest. The eyes have become glassy and she will not respond to pin pricks. The temperature becomes lower rather than higher as is indicated by the name.

Milk fever is caused by a lowering of the calcium salts of the blood.[1] Reducing the calcium salts of the blood by intravenous injection of sodium citrate brings about symptoms analogous to milk fever. Intravenous injection of calcium chloride brings about rapid recovery. The lowering of the blood calcium to produce milk fever can be explained by the fact that whole milk containing about 20 times the concentration of calcium that blood does is rapidly being produced and the calcium is being withdrawn from the blood, the mechanism for releasing calcium from the body stores replenishing the blood is not functioning. This explains why leaving most of the milk in the udder when milking for the first days following calving helps prevent milk fever.

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[1] PETERSEN, HEWITT, BOYD, AND BROWN. Jour. Am. Vet. Med. Assn. 79:217. 1936.

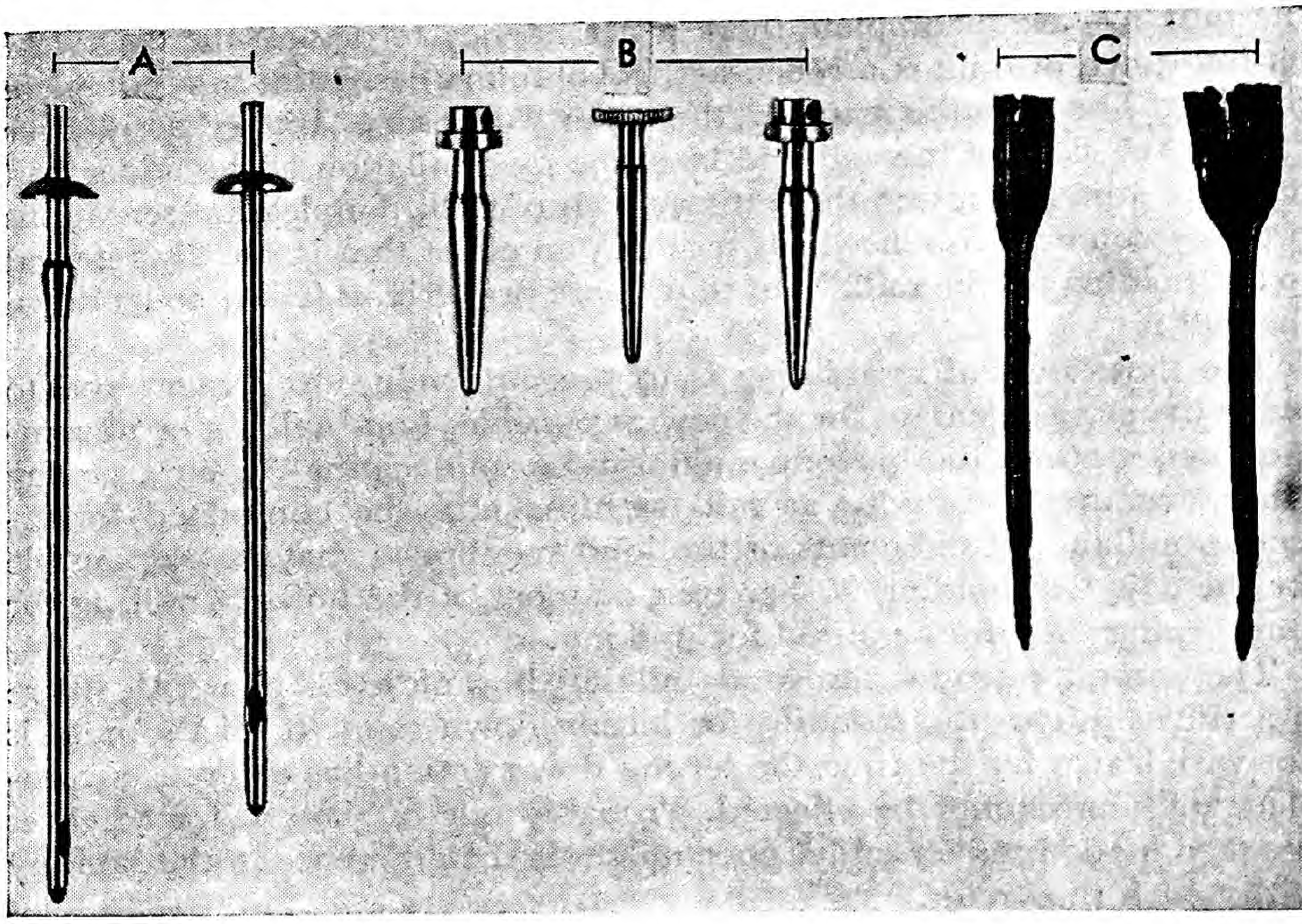

Fig 81. Milk tubes, teat plugs, and teat dilators: *A*, two types of milk tubes —self-retaining on the left; *B*, three types of teat plugs; *C*, wax teat dilators.

Milk fever may be cured by either the intravenous or the subcutaneous injection of calcium gluconate or by insufflation of the udder with air. By injecting calcium gluconate (200 cc. of a saturated solution) the calcium of the blood is restored, and recovery is sudden. Insufflating the udder with air to a pressure that stops milk secretion, stops the drainage of calcium from the blood and permits gradual building up of the blood calcium from the body stores.

For air insufflation of the udder, a teat canula or milk tube (Fig. 81) is inserted in the teat and air is pumped into the quarter, first passing through a cotton filter. Each quarter is inflated with a pressure equal to that which the maximum milk pressure exerts in a well-distended udder. Extreme precautions must be taken to prevent infection. The ends of the teat must be washed in an antiseptic solution, and the teat canula or milk tube must be sterilized by boiling. With the best care possible, infection frequently follows this treatment. For this reason the safest treatment for milk fever is the intravenous injection of calcium gluconate.

CARE IN MILKING

The object in milking is to perform the act in such a manner as to obtain all of the milk in the udder. As has been shown previously, when

the milkings are incomplete there is a tendency to dry-off the cow. The letting-down of milk is a reflex act (involuntary) essential to a complete milking. The stimulus causing the reflex is sensory. Immediately after calving the sight of the calf and later the manipulation of the udder and teats are stimuli causing the letting-down of milk. Unpleasant sensations produce counter stimuli which result in an effect that is usually referred to as "holding up the milk" but that, more properly, is failure to let down the milk.

The first essential in milking is to prevent undue excitement and to make the act as pleasant for the cow as possible. Loud talking or uncommon noises about the barn at milking time, mistreating the cow, or any other uncommon activity at milking time must be eliminated for effective milking. Excitements of the kind mentioned may be responsible for the cow withholding 20 per cent or more of the milk, as well as for lengthening the time required for milking.

The second essential for good milking is rapidity. Apparently there is a time limit to the stimulus for letting down milk. If all the milk is not withdrawn by the time the letting down action has expired, a complete milking cannot be effected. Probably one of the chief differences between a good milker and a poor milker is the difference in the rapidity with which they milk.

Methods. There are several different methods used in hand milking, differing chiefly in the manner in which the teats are grasped. The most common and preferred method is the full hand grasp with the thumb and index finger encircling the teat at the base, closing off the teat system with pressure when the milk is to be expressed. Forcing the milk out is then effected by applying pressure on the teat by closing the finger tips against the palm of the hand. A modification of this method consists in bending the thumb so that the knuckle is against the teat, closure of the teat canal being effected by the index finger pressing the teat against the thumb. The milk is then forced out by applying pressure as in the former method. A third method, sometimes called the strip method, consists in grasping the teat at the base between the thumb and forefinger. By pressure the teat canal is closed, and by sliding the pressure toward the end of the teat the milk is expressed.

Some people moisten the hands in milking. This practice is to be condemned not only because it is unsanitary and results in contamination of the milk but also because the moistened teats will become sore when they are exposed to the cold.

The order of milking the teats is not important. It is most common however, to first drain the milk accumulated in the cisterns of the front teats, then to do the same for the rear teats, and then to return to the front teats, when the major portion of the milk should be completely let down.

Drawing out the last milk is known as stripping. Care should be taken to strip as rapidly as possible in order to avoid making the cow a stripper. If the stripping action is prolonged, the cow soon adjusts herself to the

situation and the milk is let down slowly over a long period. When this habit is formed, it is difficult to break.

Milking the heifer. The way in which a heifer is trained will largely determine how she will react to milking when mature. If at the beginning a heifer develops an unfavorable attitude toward milking, she is likely to continue this attitude and become a "kicker" or a cow that holds up her milk.

For breaking in a heifer, the training should start several weeks before calving. She should first be placed in a stall with the rest of the milking cows to become accustomed to the surroundings. She should be brushed daily and treated gently, preferably by the person who will milk her following calving, in order that her confidence may be gained. When milking is started, special effort should be made to make the act as pleasant as possible. Severe remonstrations for kicking or misbehavior result in an attitude of antagonism that may become permanent. When this becomes the case, the suggestion of milking becomes a stimulus for fight; this is not conducive to good behavior during milking and reacts against stimuli for the rapid letting down of milk.

Milking before calving. While there is no evidence that milking a cow before calving has any detrimental effect upon the subsequent milk production, there is no evidence that it is at all necessary. Recent work has shown that the accumulated milk in the udder will produce only a maximum pressure equivalent to 40 mm. of mercury when secretion ceases; thus, by refraining from milking, no more than pressure equivalent to 40 mm. of mercury will be developed, and there is no evidence that such a pressure is harmful. Milking before calving removes the colostrum milk and deprives the calf of this essential first food.

Milking after calving. It is usually not necessary to milk the cow until 12 hours after calving. For the first two days, as a precaution against milk fever, it is well not to remove all the milk.

Hard milkers. Frequently the sphincter muscles encircling the streak canal are overdeveloped or lack elasticity; this condition results in hard milkers. Not only does it require more energy to milk these cows but also more time. In some cases the sphincter muscles may be expanded to some extent by strong milkers. Inserting "teat expanders" (Fig. 81) in the form of rubber or metal plugs into the streak canal in the interim between milkings will also help. However, fully overcoming hard milking requires a delicate surgical operation in which the sphincter muscles are partly cut. If too many of the sphincter muscle fibers are cut, the teat may leak milk.

Sometimes one or more teats become hard to milk because of a wart-like growth from the walls of the teat system. This growth is known as a spider. The only remedy for this condition is a surgical operation by an experienced veterinarian. Unless carefully done such an operation is apt to cause mastitis.

Drying-off cows. Frequently a real problem is encountered in drying-off high producing dairy cows for the necessary 6 weeks' rest period. It

has usually been advised that cows should be dried-off by lengthening the intervals between milking and then removing only a portion of the milk in order to partly relieve the pressure in the udder. It is usually advised to begin by milking but once a day, then once every two days, and lengthening the interval until the time that they are completely dried-off. To reduce the stimulus for milk secretion, the grain allowance is markedly reduced during the drying-off process. This has a tendency to defeat the purpose of the drying period, which is to build up the body reserve for the next lactation. Another objection to drying-off cows by lengthening the intervals between milkings and to remove only a part of the milk is that the milk produced under such conditions is not normal. When milk is left in the udder for more than the normal length of time, its composition is changed and it takes on some of the characteristics of colostrum milk.

A more desirable way of drying-off cows is to stop milking completely whenever the rest period is to begin, regardless of the amount of milk produced.[1] After the last milking it is desirable to carefully wash and dry the teats and then dip them in collodion to seal the ends of the teats. This will prevent entrance of organisms into the teat through the streak canal. It has been shown that when the milk is not removed, a maximum pressure is soon developed at which milk secretion ceases and resorption of the milk begins. Carefully controlled experiments have shown that drying-off cows by this method has no detrimental effect upon the milk produced or upon the bacteria content of the milk in the subsequent lactation.

Leaking teats. There are two conditions producing leaking teats. In one the sphincter muscles are too weak to effect a closure of the streak canal against the pressure of the milk in the udder. In the other there is either a natural fistula to the teat cistern or one caused by a teat wound extending into the teat cistern. There is no known method by which the sphincter muscles may be strengthened. The only practical solution to the problem of leaky teats due to weak sphincter muscles is to seal the ends of the teats after each milking by dipping them in collodion.

The fistula, whether it is natural or produced by a wound, may be closed by cauterizing it either with a hot iron or by other surgical means. The cauterization must be done when the cow is dry.

Sore teats. Sore teats may be caused by exposure to the cold, particularly when wet; by injury, such as wire cuts or bruises; and by a number of infections, of which cowpox is the most common. Whatever the cause, sore teats are a source of extreme annoyance during milking and result in losses from spilled milk and incomplete letting down of the milk.

In all cases of sore teats the pain due to milking may be ameliorated by bathing the teat in a warm salt solution (one teaspoonful of salt to one quart of water) to soften the sores, and then applying vaseline. In the case of severe wounds and bruises, the wound should first be cleansed with a disinfectant solution, and then medicated vaseline should be ap-

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[1] Wayne, Eckles, and Petersen. Jour. Dairy Sci. 16:69. 1933.

plied. In severe cases the milk should be withdrawn by means of a milk tube.

Warts sometimes cause sore teats or discomfort to the milker. Warts are usually temporary. Vaseline or olive oil applied daily will prevent their spreading and speed up their disappearance. Large warts may be removed by clipping them off and then touching the wound with a stick of caustic potash or a 5 per cent solution of silver nitrate.

Use of a milk tube. In case of severe teat injury the best means of withdrawing the milk is by using a milk tube. The tube should be inserted in the injured teat when the other teats are milked, as a more complete drainage of the milk is effected at this time than when inserted following the milking of the normal quarters. In using a milk tube, extreme care must be taken to guard against infection. The tube must be sterilized by boiling and the end of the teat must be carefully cleansed with a disinfecting solution such as lysol before the tube is inserted.

Why cows leave the herd. Cows are disposed of for the following reasons:

1. Surplus stock
2. Poor producers
3. Old age
4. Accidents
5. Deaths
6. Disease
7. Sterility

No adequate study has been made to show what proportion of the cows disposed of annually falls into each of the categories listed. For any one herd the distribution would vary greatly, depending upon the incidence of disease and the amount of surplus stock. Scattered cow testing associations' reports indicate that from 15 to 20 per cent of the cows disposed of are sold because of low milk yields. Sterility and disease constitute the cause of disposal of more than 60 per cent of the number. Misner estimated that less than one-third of the disposed animals were sold for productive purposes in a region of relatively great demand for cows.

The length of productive life of cows. There is a scarcity of authentic material on the length of time cows are productive. That there is great variation among cows as to the age at which production ceases and they are eliminated from the herd, is well known. Cows have been known to produce and reproduce when 20 or more years of age, although this is rare. It is a commonly accepted belief that cows are productive for 5 years, although individual studies vary from 3.6 to 7.5 years. Actual studies [1] revealed the following ages of productivity of cows:

Delaware County, N. Y.	3.6 years
Chester County, Pa.	4.34 years
Lenawee County, Mich.	4.52 years
Mason City, Iowa	4.5 years

[1] U. S. Dept. Agr., Prof. Papers, Bul. 341.
MUNGER. Ia. Agr. Expt. Sta. Bul. 197. 1921.

In addition, Dow[1] reports one heifer replacement for 5.5 cows as adequate and Rasmussen[2] 6 years as the average productive life of cows. Estimates by farmers run as high as 7.5 years by 131 farmers in New York.[3]

PROTECTION AGAINST FLIES

Damage. The damage done to cattle by flies is not known. Some people believe that the generally supposed damage of flies to milk production is overestimated. Flies, however, are responsible for great economical losses due to preventing cattle from grazing, the spreading of disease, the damage caused to hides and flesh, annoyance during milking, and the great sums of money expended in combating them in the form of sprays, screens, flytraps, and other devices. The more important flies attacking cattle are stable flies, horn flies, house flies, warble flies or cattle grubs, horse flies, and screw worm flies.

Stable fly. The stable fly[4,5] resembles the house fly in appearance. It differs from the house fly in that it has piercing mouth parts that penetrate the skin and with which it sucks blood. The annoyance to cattle is due to the pain caused by piercing the skin. Eggs of the stable fly, which develop into adult flies in about two weeks, are laid in manure and decaying straw.

Horn fly. The horn fly is smaller than the stable fly. It gets its name from the fact that it roosts at the base of the horns. This fly has a painful "bite," sucking blood as does the stable fly. The horn fly may be recognized by its habit of spreading the wings when feeding. It breeds in fresh manure, and requires ten days to develop from the egg to the adult fly.

House fly. The house fly[6] does not bite the cows but annoys them by crawling over their skin, and it is a general nuisance in the barn and milk house. It breeds in manure and in moist decaying matter of all kinds.

Warble fly. The warble fly[7] or heel fly or cattle grub is found in all parts of the United States. While this fly does not bite, it is one of the most annoying to cattle. It deposits its eggs on the hair of the legs, on the body, and one species on the heels, and when in the act of depositing eggs, it causes fear in the animal that often results in a stampede. The eggs hatch and the larvae burrow through the skin and tissues to find their way up under the skin of the back, where they pupate. Damage to the animal is caused when the larvae burrow through the skin and tissue and when the pupae dig holes in the skin along the back from which they exit in early spring. Aside from the adult stage, the whole life cycle is spent on the animal. Control lies in the destruction of the larvae.

Since the warble fly will travel considerable distances, control of this

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[1] Dow. Me. Agr. Expt. Sta. Bul. 361. 1932.
[2] Rasmussen. N. H. Agr. Expt. Sta. Bul. 2.
[3] Misner. N. Y. Agr. Expt. Sta. Bul. 409. 1922.
[4] U. S. Dept. Agr. Farmers' Bul. 1097.
[5] Diseases of Cattle, p. 504. U. S. Dept. Agr. 1923.
[6] Howard and Hutchinson. U. S. Dept. Agr. Farmers' Bul. 851.
[7] Bruce and Sheely. Fla. Agr. Expt. Sta. Bul. 86.

pest must be an area undertaking. The pest can be controlled by destruction of the larvae before they emerge. One method applicable to small herds is to squeeze the larvae out and destroy them. The more common method is to destroy them *in situ* in one of several ways. Dusting about one and one-half ounces of a mixture of one part derris powder containing 5 per cent rotenone and nine parts wettable sulphur along the back and then brushing vigorously against the hair with a stiff bristled brush is effective. Another satisfactory method is to make up a solution of ten ounces derris powder and four ounces neutral soap with one gallon of water and apply along the back with a stiff bristled brush. For large-scale operations spraying with a sprayer that will develop 200 or more pounds of pressure is preferred. The spray is made up of five pounds derris powder and ten pounds wettable sulphur in 100 gallons of water. About one-half gallon will be required per head.

Fly control. Flies may be controlled by destroying the breeding places, by use of various repellants, and killing the adult fly. In recent years a number of insectcides have been developed that are effective in killing flies when they contact a sprayed surface. Among this list are DDT, TDE, toxaphene, benzene hexachloride, chloridane, and methoxychlor. DDT (dichloro-diphenyl-trichloroethane) has been used the most extensively for the spraying of barns, milk houses, and cattle. It has been very effective in controlling the fly nuisance when properly used except in some cases where it has been reported that the flies have developed a tolerance for the drug to the extent that 50 or more times the amount of the material is required to to be effective.

Recently because of the possible injury to human health DDT and others of the chlorinated hydrocarbons except methoxychlor have been removed from the list of recommended insecticides to be used as sprays for milking cows or for barns or milk houses. It has been shown that when DDT is ingested it will be absorbed into the system and will be deposited in the body fat and in the milk. Because of the deposit in the body fat the drug will be found in the milk for up to 60 days after the last ingestion of the substance. Spraying young stock and bulls with DDT is not contra-indicated because there is no evidence that the ingestion of DDT in amounts as would be gotten from this source is injurious. Likewise manure piles and other places where flies may breed may also be sprayed with DDT provided that milking cows are kept away.

Methoxychlor is now the only one of this group of insecticides that is recommended for spraying dairy barns, milk houses, and milking cows. This substance is held to be noninjurious to humans in the amounts that could possibly get into the milk.

Spraying of barns. Methoxychlor should be used for the spraying of the barn and milk room. This drug is obtainable in 50 per cent wettable powder and should be made up to a .5 per cent solution with water. DDT may be used as a spray for other places where flies gather but where cows in milk do not contact. DDT for this purpose should likewise be made up to a 2.5 per cent solution either in oil or in water. One gallon of either

DDT or methoxychlor solution will cover about 300 square feet of surface. Spraying should be repeated each two months during the fly season. To be most effective all surfaces where flies alight should be sprayed. This includes walls, ceiling, supports, screens, stanchions, and the outside where flies usually roost around doors and windows.

Spraying cattle. Both DDT and methoxychlor are very effective in the control of the house fly and the horn fly and less effective for the biting stable fly when applied to the animal. They are not effective in the control of deerflies and are of no value against warble flies and bot flies. Only methoxychlor should be used on milking cows, while DDT may be used on bulls and young stock. Only wettable powder made up with water should be used for cattle sprays. A .5 per cent solution of methoxychlor and a 2 per cent solution of DDT should be used. About two quarts are required per cow per spray. Either spray must be applied every three weeks during the fly season.

Older methods of using fly traps, electric killing devices, and fly repellents do not seem to have a place in the fly control program that is not taken care of more effectively by the use of DDT. Repellents do not reduce the fly population but merely protect the animals by keeping the flies off. Oil base repellents have been shown to increase the body temperature of the animal and to cause skin burns.

Lice. There are three species of lice that commonly affect cattle, causing damage through irritation of the animal. Two species are blood sucking (the short-nosed cattle louse, *Hæmotopimus eurysternus*, and the long-nosed louse, *Linognathus vituli*) and the third is a biting louse (*Trichodeates scalaris* or red louse). Due to the itching caused by the lice, affected cattle rub themselves against any available object or lick themselves, either of which will cause loss of hair, leaving denuded areas. Cattle engaging in excessive rubbing or licking should be investigated for possible infestation of lice. The neck, the back of the head, and the back are the most probable places to look for lice. Lice reproduce by laying eggs called nits. The nits hatch in about ten days.

Lice are controlled by the adequate use of DDT. Before the cattle are stabled and while the weather is still warm, all parts of the body should be thoroughly wetted with a 0.25 per cent DDT or methoxychlor spray made up of from wettable powder. One such treatment is usually sufficient, since there will be sufficient residual DDT or methoxychlor on the hair to kill lice that hatch from eggs on the body at the time of the spray. During the winter in cold climates lice may be effectively treated by dusting with a 5 to 10 per cent DDT or methoxychlor dust.

Chapter 35

THE MILKING MACHINE AND MILKING

THE LARGEST SINGLE LABOR ITEM IN THE CARE OF DAIRY COWS IS THAT REquired for milking.[1] Estimates of the per cent of time required for milking vary from 53.6 per cent of all labor requirements for the milking cow to 41 per cent of the total labor requirements for the whole herd. While the time required to milk a cow varies with the milker, the amount of time needed depends upon the amount of milk a cow yields and the ease with which she milks; on the average, seven minutes are required per milking, or 14 minutes per day. This means that approximately 75 hours are spent annually in milking each cow. Because the labor requirement is so large, and because milking requires daily and exact attention, hired labor is difficult to secure; therefore a great deal of interest has been manifested in the mechanical milker.

The history of the development of the milking machine, the different types of machines, the comparison of hand and machine milking, the economical phases of machine milking, and the care of the milking machine are subjects with which the student of dairying should be familiar.

History of the milking machine.[2] Attempts at making milking machines began in the United States as early as 1819. All of the earlier types were failures; this fact did much to establish the early prejudices against milking machines. The earliest types used tubes inserted in the teats. These were followed by pressure devices to squeeze out the milk, and they in turn were followed by suction machines of various types.

The milk tube milking machines were soon discarded because of the injuries to the teats and the spread of disease. It is possible to draw the milk from the udder by means of the milking tube, but in inexperienced hands the end of the teat is frequently injured; and unless the tube is sterilized before each insertion, mastitis infections are generally spread.

Although a large number of patents have been granted on the pressure types of milking machines, none of them are now in use. In reviewing the development of milking machines, Erf describes machines of this group using rollers, pads, plates, belts, and mechanical fingers. All were based upon the principle of hand milking: that is, applying pressure to the teat, beginning at the upper portion and working downward. The force for applying the pressure was furnished by means of belts, shafts, and in some cases, by pneumatic devices. All of these types proved unsatisfactory because the amount of labor involved in their operation was

[1] MISNER. N. Y. Agr. Expt. Sta. Bul. 409. 1922.
MUNGER. Ia. Agr. Expt. Sta. Bul. 197. 1921.

[2] ERF. Kans. Agr. Expt. Sta. Bul. 140. 1906.

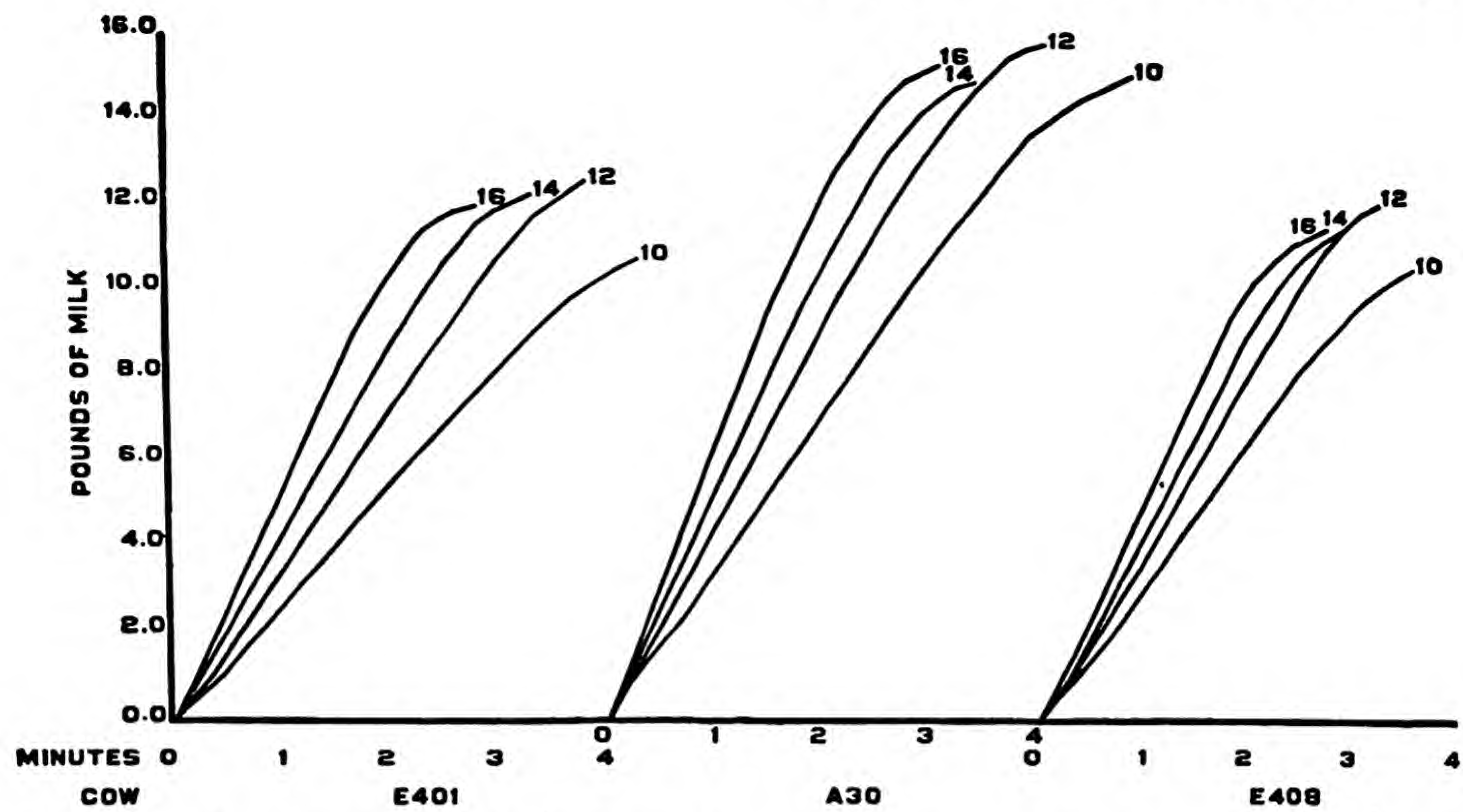

Fig. 82. Here is shown the effect of varying the negative pressure (vacuum) from 10 to 16 inches of mercury upon the rate of milk withdrawal in three cows.

large and also because they were inflexible and annoying to the cows. Most of the machines had to be securely strapped around the body of the cow. With some types the power was furnished by hand, and more work was expended in turning the machine than would have been expended in hand milking.

The first suction machine, patented in 1860, was operated by continuous suction. While this type of machine was much more satisfactory than any of the previous types, it found disfavor principally because of the injury it caused to the teats. The continuous vacuum on the teats caused a severe congestion.

In 1895 the Thistle milking machine, which proved to be a distinct advance in the evolution of milking machines, was developed. This machine is usually credited with being the first to use intermittent suction or pulsation, which is the basic principle of all modern machines. The Thistle machine was crude and complicated as compared with the modern machines. The pulsations were created at the vacuum pump, and by the time they reached the teat cups they were not sharp and well defined. A large vacuum pump and a large amount of power were needed, since all the air in the entire vacuum system had to be expelled with each pulsation.

The next important advance in the development of the milking machine occurred in 1902 when Lawrence and Kennedy of Glasgow, Scotland, developed the first mechanical milker with the pulsator on the lid of the milker and the pressure created by vacuum.[1] This principle permits the maintaining of a continuous vacuum in the vacuum system and the giving of sharp and distinct pulsations at the teat cup. All modern machines

[1] Woll and Humphrey. Wis. Agr. Expt. Sta. Res. Bul. 3. 1909.

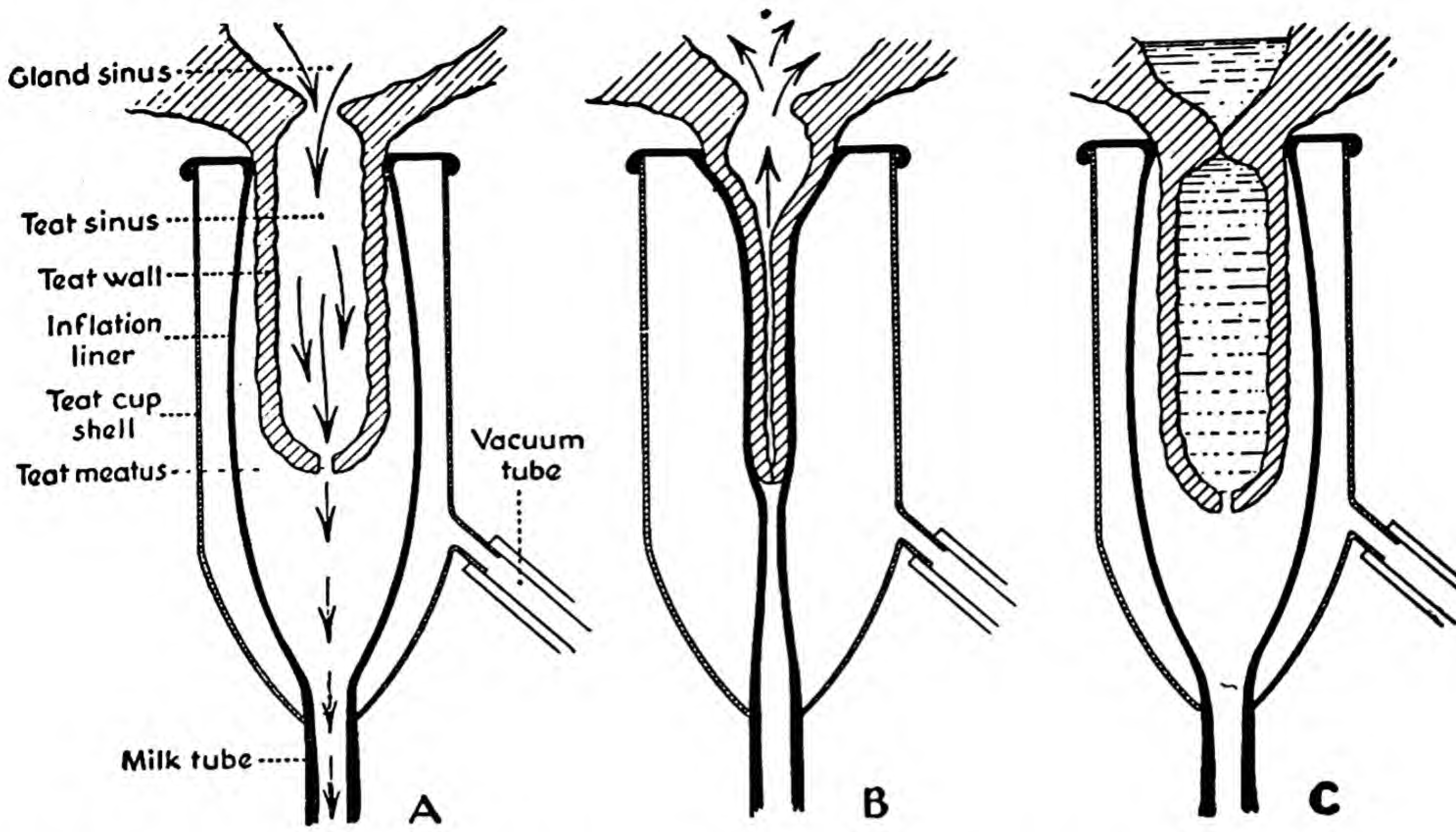

Fig. 83. The action of the mechanical milker is shown in the above diagrams.

embrace this principle, although different mechanical means are used by different manufacturers.

Types of modern milking machines. Although all modern milking machines use negative pressure for extraction of the milk there are differences in the mechanical means used. Mechanical milkers fall into two groups: (1) single action and (2) double action.

Single action. The machines falling in the single action class have teat cups without rubber inflations, and depend upon the negative pressure being applied from a piston pump or the like in which that pressure is created by the outward stroke and release is afforded by the return stroke. The pulsation rates are, therefore, established by the speed of the pump. The level of negative pressure increases from the beginning of the stroke till the end, when partial release is afforded. If there is complete release of negative pressure, the teat cups will not remain attached.

The negative pressure is confined to the milk tubes, teat cups, and head. On the outward stroke, the milk gathers in the head set over a pail and on the backward or release stroke the milk is dropped into the container. Some of the machines are constructed so the head will fit over a milk can. In spite of the partial or nearly complete release for one-half of the cycle the teats become congested from these machines.

Double action. The double action machine is characterized by a teat cup having a rubber inflation or lining on the inside. This type of machine requires a constant negative pressure coming from what is known as a vacuum tank. The vacuum tank may supply the negative pressure to where it is needed through a pipeline, or both the motor and the vacuum tank may be portable. These machines are equipped with pulsators, devices that make or break the negative pressure. These pulsators may be

adjustable or regulated electrically at a constant rate. The negative pressure from its source usually is connected to the pulsator which is customarily placed on top of the milking machine pail.

From the pulsator the negative force is directed two ways, one into the milk pail and the other to the outside of the teat cups. The full negative pressure always goes to the outside in the teat cups. In many cases the force going to the pail is reduced by what is known as a check valve. The amount of reduced force through the action of the check valve varies but usually is about equal to two inches of mercury pressure. On such a machine operating with 14 inches of mercury negative pressure in the pipeline will deliver not over 12 inches to the teats. Those machines that do not have check valves can deliver the full force of the pipeline negative pressure to the teats.

The negative pressure in the pail is applied through the milk tube to the teats on the inside of the rubber inflations. This force is constantly applied. The teats, however, are alternately protected against the congesting effect of this force by the collapse of the inflations due to release of the negative pressure in the outside shell. Upon release in the shell, the rubber inflations collapse with sufficient force to produce a substantial massaging action.

The double action machines are subdivided into the suspended or short tube and the floor or long tube types. The suspended machines, as the name indicates, are suspended from a surcingle and has short milk tubes, each tube from the teat cup being connected to the head of the machine. The floor type of machine usually has the milk tubes and vacuum tubes from each teat cup enter a claw to which there is a single vacuum tube and from which the milk is taken to the pail in one milk tube.

The releaser system. The releaser system employs the regular milking machine principle for milking, but instead of the milking machine pail being used, the milk is drawn through sanitary piping into the milk room. Vacuum is employed in the transport of the milk into one of two containers. When one container is filled, or when one or more cows have been milked, the vacuum is released from the filled or partially filled container to permit emptying its contents, and the other container is evacuated. This is accomplished by the so-called releaser device.

The releaser system was developed in New Zealand and Australia, where it is extensively used. In this country a modification of the releaser system is used in the so-called "milking parlor." Here the milk is drawn directly from the cow into a glass container suspended from a scale and located above the stall. The milk is drawn from the glass container into the milk room by the releaser method. The releaser system has reached its highest development in the Roto-lactor owned by the Walker Gordon Company of New Jersey. The Roto-lactor consists of a revolving table containing 50 stanchions and one releaser unit for each stanchion. The table makes one revolution in 12½ minutes; during this time a cow is milked. Many special features are incorporated in the Roto-lactor system. Every machine is washed and sterilized by automatic arrangements

following the milking of each cow. Special alleyway arrangements are used in taking cows to and from the Roto-lactor to minimize labor requirements and confusion. The cows are washed as they enter the machine and dried before the milking machine is attached.

Cows are not stripped following milking by the releaser type; toward the end of the milking the udders are massaged to facilitate getting all the milk in the udder.

Comparison of hand and machine milking. A number of experiments have been conducted to test the relative efficiency of hand and machine milking. Only the more recent work is worthy of note as only such would include studies of the modern perfected milking machine. The Iowa Station [1] compared hand milking with the milking of one of the modern machines by alternating the two for a period of 51 weeks. The average daily milk yield of 20.22 pounds for the machine and 20.18 pounds for the hand milking shows no significant difference for the two methods. This is in accord with previous studies using the same method of approach.[2]

Recently Dahlberg [3] reported on comparisons of hand and machine milking for a group of seven cows that were milked by machine the first, second, and fourth lactation periods, and by hand the third lactation period. He observed that cows milked by machine were not quite so persistent as those milked by hand. The differences were not great and have no bearing upon the advisability of using machines.

It may be concluded that machine milking is probably not quite so efficient in getting the most milk as the best hand milking, but it is better than the average hand milking. It has been universally recognized that cows like machine milking as well as or better than hand milking. Most of the harmful effects of machine milking appear to be due to leaving the machine on the cow too long.

Stripping by machine. The question as to whether one should strip by hand following the mechanical milk has and still is subject to a good deal of debate. There is no argument about the desirability of removing all of the milk, for reasons that have been fully discussed in a previous chapter. The question then is one of whether all of the milk can be removed by the machine or whether it is more practical to do so by hand stripping. At the Minnesota Station it has been established that all milk that has been let down can be removed by the proper manipulation of the teat cups and massaging of the udder.

Any milk in the teat cistern must be removed to the action of the mechanical milker. The problem is that of getting the milk into the teat cisterns. As milking progresses, the lower part of the udder becomes soft and flabby due to the release of the pressure caused by the let-down milk. As a result these soft tissues are gradually drawn into the teat cup first

[1] MATHEWS, SHAW, AND WEAVER. Ia. Expt. Sta. Bul. 248. 1929.
[2] SMITH AND HARDING. N. Y. Agr. Expt. Sta. Bul. 353. 1912.
WOLL. Calif. Agr. Expt. Sta. Bul. 311. 1919.
[3] DAHLBERG. N. Y. Agr. Expt. Sta. Bul. 654. 1935.

to slow down the flow and finally to completely block the passageway for the milk from the gland cistern to the teat cistern. By drawing the teat cups downward to reopen the passageway and, simultaneously, with the free hand, massaging each quarter to facilitate drainage of the (sp) tortonous ducts, every bit of the milk that has been let down can be withdrawn by the machine.

While all of the milk can be removed in all cases by proper manipulation of the teat cup assembly, there are cases in which special skills are required to accomplish this fact. Sometimes growths occur in the walls of the teat cistern that will necessitate drawing the teat cups down so far before passage for the milk is opened that they are apt to drop off. Different anatomical anomalies of teats and lower udder also contribute to difficulties in stripping by the machine. The number of cases that present serious difficulty is few and perhaps the best solution for the out-of-the-ordinary difficult ones is hand stripping.

There are three reasons why cows should be stripped by the machine rather than by hand.

1. Time and effort is saved. One extra trip to the cow at each milking is saved.
2. The cows are kept in better milking habits. Hand stripping, particularly if prolonged has a tendency to make strippers out of cows. Many cows will develop the habit of not letting down all of the milk to the machine and require a second let-down to the stimulus of hand stripping.,
3. Most of the visible particle contamination in milk comes from the practice of hand stripping.

The question of how much milk may be left in a quarter without damaging effects is still not settled. It is not feasible to spend enough time to get the very last milk out. Milk continues to drain from the network of ducts for some time after milking is completed. The all important point is to so carry on the milking that the milk is forced out of the alveoli. From the evidence now available, leaving a few ounces in a quarter provided the alveoli are emptied is not deleterious.

Principles of milking. Milking is accomplished only by the proper application of force in which the sphincter muscles surrounding the teat meatus are stretched to make an opening for the milk to be discharged. In hand milking the upper part of the teat cistern is closed tightly by the hand to prevent the milk from flowing back into the udder cistern and pressure is applied to the milk-filled lower part of the teat. The increased pressure inside of the teat stretches the sphincter muscles and the teat meatus is forced open. Measures by the author of the pressures exerted in hand milking varied from 20 to 35 inches mercury pressure with each squeeze by seven different hand milkers. In general the faster milkers applied the greater force, although this was not always true. In some cases failure to close the upper part of the teat cistern soon enough or to close them completely caused some of the teat contents to flow back into the gland cistern and a proportionately small stream was evacuated with each squeeze.

In machine milking the pressure on the inside of the teat is left un-

changed. The pressure inside the teat cup is lowered by the machine so that the normal pressure inside the teat in relation to the outside pressure becomes great enough to force the meatus open and allow the milk to flow out. In the double action machine the milk is not squeezed out, as is claimed by some. The milk flows out of the teat only when the inflations are distended by the application of negative pressure in the outer teat cup. Upon collapse of the inflation milk stops flowing.

The relation of negative pressure levels and speed of milking. Other things being equal the greater the negative force the faster the milk will be withdrawn. There is a great difference among cows in the amount of force required to milk at a satisfactory rate. In so far as the force required in the speed of milking, it is due to the strength of the muscles surrounding the meatus. Injury which produces scar tissue around the meatus usually increases the force that is required to withdraw the milk speedily. There are other factors than hardness of milking that impedes the rate of milk withdrawal and that are not improved by increasing the amount of force. One is the failure of the cow to let down her milk as fast as it can be taken away and the other and more common are the obstructions (either natural or developed) in the upper teat cistern that will not permit the milk to enter the teat as fast as it can be withdrawn.

The best level of negative pressure to be used is still not settled. It is obvious that in herds where most of the cows are hard milkers a higher negative pressure should be used than where the cows are easy milkers. There is this interesting automatic feature about mechanical milking that for easy-milking cows a much smaller portion of the total potential negative force is delivered to the teat than for hard-milking cows. The reason for this automatic regulation is due to the fact that the greater the flow of milk in the milk tube, the greater will be the resistance to the negative force reaching the teat. For easy-milking cows the author has found as little as five inches of mercury negative pressure on the teats with 13 inches N. P. in the pail. When the milk ceases to flow, the full force in the pail will be directed to the teat.

Injury from mechanical milkers. A great deal has been said about the injury to the teats and udder caused by mechanical milkers. Misuse can cause severe damage but by proper use less force need be exerted on the teat by the mechanical milker than by hand milking. Studies by the author have revealed that, when milk flows out of the meatus, no force is exerted on the inside of the teat. With the double action machine left on for five minutes no detectible congestion or swelling of the teat was observed except in the very end. With the single action machine left on for five minutes there was a noticeable increase in both the length and thickness of the teats.

When milk does not flow through the meatus, the negative pressure extends inside the teats with damaging effects. The inside lining becomes congested and the upper part of the teat and sometimes the lower part of the udder are drawn into the teat cups where a shearing action takes place with each pulsation. These injuries invite infection and produce growths

that interfere with milking. If the mechanical milker is not attached until the milk is let down and removed soon after the milk stops flowing, no harmful effects are to be found from its use. The greatest damage comes from leaving the mechanical milker on too long.

Pulsation rates. There is a general idea that increasing the pulsation rates speeds up milk withdrawal. In trials where pulsation rates ranged from 20 to 120 per minute and the level of the negative force was kept constant, no difference in the rate of milk removal was observed. This is what was to be expected because milk is removed only during that half of the cycle when the inflations are distended. By increasing the rates the number of cycles per minute is increased but milk is withdrawn just one-half of the time.

Just what is the optimum pulsation rate is not known. When pulsation rates were slow, below 40 per minute, there was evidence of pain and some congestion to the teats. With the faster pulsation rates, danger from congestion is avoided but the amount of power to maintain the proper negative pressure levels is increased. Usually when the pulsation rates are substantially increased, the negative pressure drops particularly after a machine is attached and some time is required before it again reaches the desired level with the result that the rate of milking is reduced.

Effect of the milking machine upon the quality of milk. The bacterial and sediment content of milk drawn by the milking machine is dependent upon the care used in cleaning and operating the machine. If the machine is sterilized and handled in such a way as to prevent contamination during the milking process, milk can be produced as clean as with the best hand milking. Many certified dairies, where low bacterial and sediment content of milk is paramount, use milking machines. If the machine is not properly cleaned and sterilized between each milking, and if, through careless and slovenly methods of handling, the teat cups become contaminated in operating, the machine may be the cause of increased bacterial and sediment content of the milk. In most trials under ordinary farm conditions machine produced milk has been found higher in bacterial content than milk produced by hand milking.

The milking machine and udder diseases. The milking machine sometimes is accused of being responsible for injuries to the udder and the spreading of mastitis. While this is true in some cases, nearly all workers studying the efficiency of milking machines report no injuries or infections that can be attributed to the use of mechanical milkers. There is every reason to believe that the milking machine may spread mastitis in the same way and to the same extent that hand milking will. When cows are not stripped following machine milking or when the udders and milk are not carefully examined for abnormalities, udder troubles may become more pronounced with machine milking than with hand milking. If examinations for abnormalities are not made, the disease may become quite advanced before it is discovered, and more time will be given for the infection of noninfected cows. Also, treatment of the infected cows will be delayed, and their chances for recovery lessened.

Leaving the milking machine on the cow too long and using too great a vacuum are, predisposing factors for mastitis. Either one of these practices may injure the delicate membranes lining the teat cisterns and increase the chances of infection at the point of injury, from which infection may spread to the deeper parts of the udder.

Economy of milking machines. Whether or not milking by machine is to be advised depends upon whether one or more of the following three points are to be met:

1. To reduce the cost of milking.
2. To overcome the difficulty of securing competent hand milkers.
3. To obivate dislike for hand milking.

The cost of labor and the size of the herd are the chief factors which determine whether the use of milking machines will lower the cost of milking. The use of milking machines will reduce the time required for milking by more than 50 per cent.[1] The Iowa Station reported a saving of 52.1 per cent in the actual time required for milking.[2] The Illinois Station, from a study of hand milking on 34 farms and machine milking on 32 farms, found an average of 133.9 hours of labor for care and milking per cow per annum when milked by hand and of 81.5 hours for cows milked by machine, or a saving of 52.4 hours of labor per cow per year.[3] With the saving of time required in milking it would appear that the milking machine is a time and money saver for any sized herd. This is not true, since there are certain costs in connection with the milking machine that are constant, increasing but slightly with the increase in herd size. The chief items are depreciation at the rate of 10 per cent per annum, interest on investment, and repairs and replacements. To these must be added the cost of power and the extra labor involved in cleaning the machine. At the Iowa Station in 1929 these items amounted to a total of $172.61 for 22 cows. On the average farm with 25 cows, Illinois found that labor represented 76.5 per cent, power 13.2 per cent, and charges against the machine 10.3 per cent of the total costs of milking by machine. When the labor rate varied from 12 to 30 cents per hour, the annual saving per cow for herds with less than 25 cows ranged from $0.46 to $9.55, and for herds above 25 cows, from $2.76 to $12.37.

On farms where plenty of labor is available that would not otherwise be utilized from an economical standpoint, the labor should be used in hand milking, even at low returns per hour. Where additional labor must be employed, the milking machine begins to be a profitable investment with herds of 12 cows, with increasing savings for larger herds. When hand milking is very much disliked and it is difficult to secure competent hand milkers, the purchase and use of milking machines for smaller than 12-cow herds may be advisable.

Care of the milking machine. Like any other mechanical device, the milking machine will do good work only when properly cared for. Two

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[1] Ruehe, Breed, and Smith. N. Y. Agr. Expt. Sta. Bul. 450. 1918.
[2] Mathews, Shaw, and Weaver. *Op. cit.*
[3] Pearson and Ross. Ill. Agr. Expt. Sta. Bul. 241. 1923.

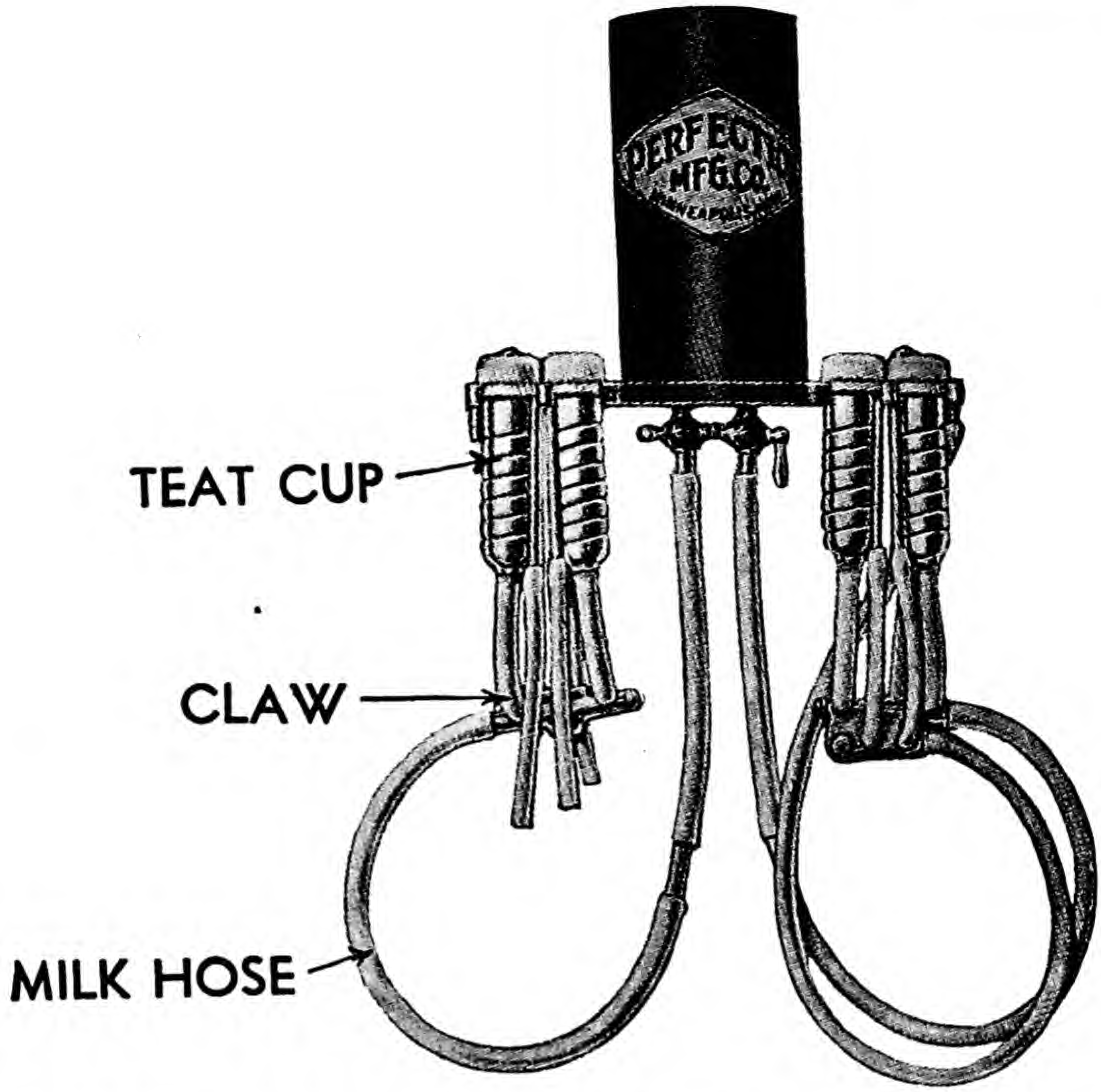


Fig. 84. Milking machine sterilizing rack. The sterilizing solution is run out of the container to fill all the parts with which the milk comes in contact during the milking.

mistakes are frequently made in running milking machines: the pulsator is not properly adjusted, and the vacuum is not properly maintained. If the pulsator rate is either too slow or too fast, the maximum efficiency of the machine cannot be attained. At regular intervals the rate of pulsation should be checked and adjusted if necessary. While the vacuum is usually prevented from becoming too great by the proper safety valve furnished by the manufacturer, the operator is frequently responsible for too little vacuum, with resulting inefficiency of the machine. Leakage in the line, in the rubber tubes, or in the pail from improper fitting of the cover may be sufficient to lower the vacuum below the point for maximum efficiency.

The milking machine frequently suffers from lack of care, particularly in the oiling of the few movable parts in the vacuum pump and pulsator. The pail and teat pumps are frequently dropped and become dented so as to permit leakage of air and resultant loss of vacuum. The rubber inflations may not be properly adjusted, or they may become cracked. Cracked or improperly adjusted inflations may leak air and draw milk into the chamber between the inflation and the teat cup shell; this results in poor milking, and sometimes in milk getting down into the pulsator. All faulty inflations and other parts should be replaced.

Replacing inflations constitutes the greatest repair expense for milking machines. It is, therefore, good economy to give special attention to those considerations that will increase the length of life of the inflations. Fat and dirt cause rapid deterioration of rubber, and their prompt and thorough removal will do much to lengthen the life of the inflations. Also undue stretching of the inflations should be avoided.

Cleaning the milking machine. It is possible to produce as clean milk with as low bacterial content by machine as by the best of hand milking; but in order to do so, special effort must be made to thoroughly clean and sterilize the parts of the machine with which the milk comes in contact. The milking machine pail may be cleaned and sterilized like any other pail—by first scrubbing it thoroughly, and then scalding it with boiling water or steam. The rubber parts, however, do not permit this treatment because they are inaccessible and also because the heat will injure the rubber.[1] It is therefore necessary to use some chemical sterilizer. For a chemical sterilizer to be effective, all of the milk must be removed.

Immediately after milking, before any of the milk has dried on the machine parts and while the machine is still on the vacuum, several gallons of cool or lukewarm water should be drawn through each unit. This is done most effectively by dousing the teat cups up and down in the water to permit water and air to be drawn through alternately. This procedure is followed by drawing through, in the same manner, one or more gallons of a hot solution of washing powder. Use two heaping tablespoonfuls of any good washing powder to a gallon of water. The teat cup liners should be brushed, especially the portion extending outside the teat cup shell.

After the milk has been removed, the tubes and teat cups with the liners may be immersed in the chemical sterilizing solution, or they may be placed in the "sterilizing rack." (Fig. 84.) The sterilizing rack is a device so constructed that the teat cup assembly with the milk tube is automatically filled with the sterilizing solution. In either case the equipment should be left in the sterilizing solution until just prior to the next milking, when it should be rinsed with clean water.

The sterilizing rack has several advantages over the immersion method of sterilizing. The outside shell of the teat cups is not exposed to the action of the solution, and since the contents of the tubes and teat cup assemblies are discarded after each usage, fresh sterilizing solution is used for each time of sterilization. In continued use of the solution, followed when the equipment is immersed, the solution becomes contaminated and weakened.

The sterilizing solution may be made up according to directions from a large number of sterilizers on the market, or it may be made at home. Some recent work indicates that a lye solution not only is an effective disinfectant but also is an excellent cleansing agent that prolongs the life of rubber. A stock solution of lye is made by dissolving a 14-ounce

[1] Burgwald. Jour. Agr. Res. 34:27. 1927.

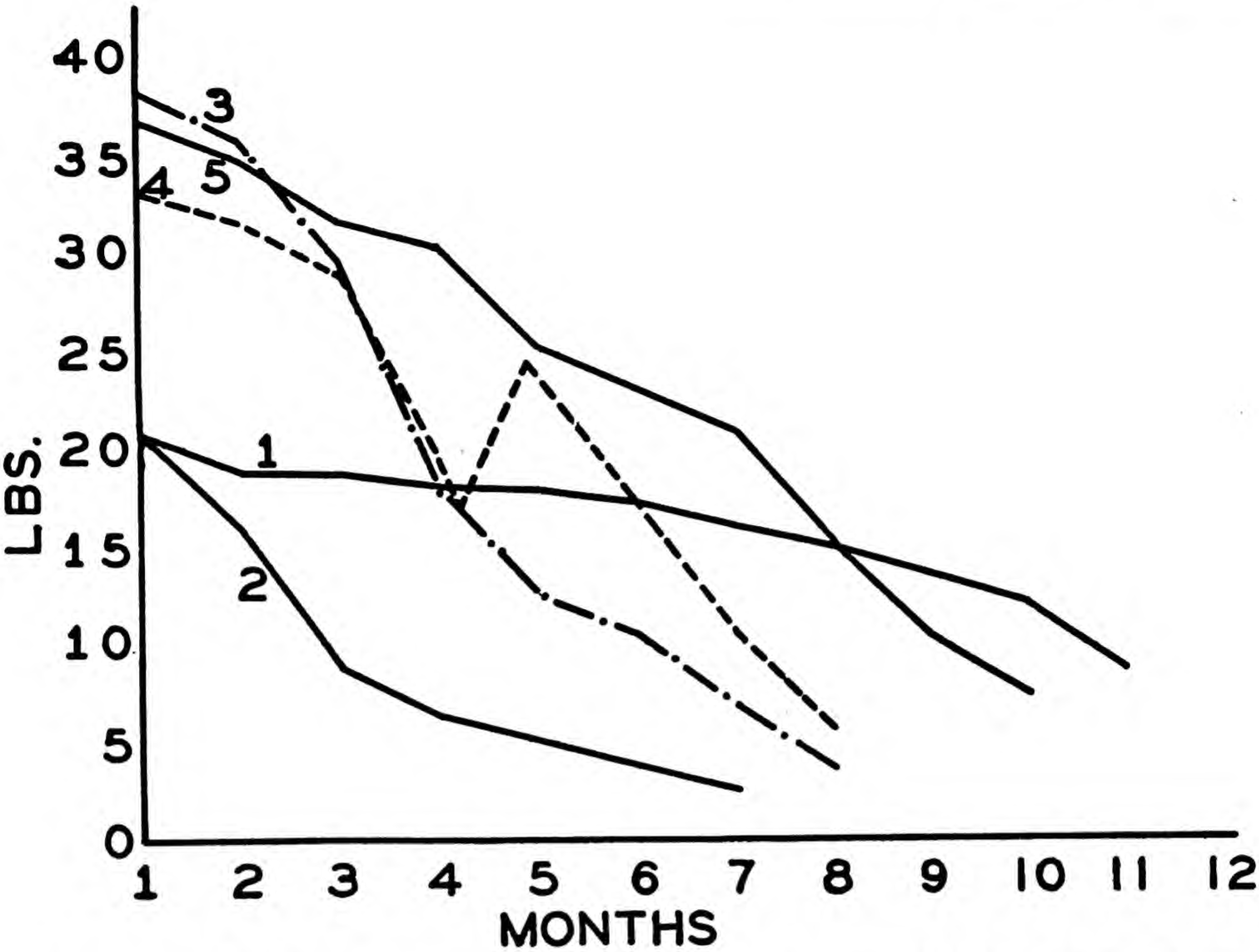


Fig. 85. Incomplete evacuation of the udder causes rapid drops in milk flow. Lactation curves are shown for five consecutive lactations of a cow that let down her milk well on the first lactation resulting in good persistency. During the second, third, and fourth lactations she developed the habit of letting down the milk completely on infrequent intervals resulting in steep slopes of the lactation curves. For two weeks in the fifth month of the fourth lactation the udder was emptied after each milking by the injection of oxytocin. Note a more than 50 per cent rise in milk production. During the fifth lactation she was milked by a milker she responded to with complete let-down of milk resulting in a 61.2 per cent increase in milk for 305 days.

can of lye in a gallon of water. One-half pint of the stock solution is used to one gallon of water in making up the solution for use in sterilizing.

A homemade hypochloride stock solution may be made as follows: Dissolve one pound of sal soda in one gallon of water, then add one 14-ounce can of chlorinated lime, and stir or shake vigorously; let this mixture set until the sediment has settled to the bottom; then syphon off the clear supernatant liquid into a dark colored glass bottle, and stopper the bottle tightly. One quart of this stock solution will make 20 gallons of sterilizing solution.

The vacuum line should be flushed out occasionally. Moisture from the milk condenses in the pipes, and sometimes milk may be sucked over, resulting in high bacterial contamination.

Proper milking. To get all of the milk out of the udder at each milking is the one fundamental objective in milking. Failure to do so is an important cause for premature drying up of cows. Some cows for unknown reasons are not able to let down all of the milk but retain constant quantities to leave a "meaty" udder after milking. One such cow was found to retain eight pounds of milk, the amount ascertained by injection of oxytocin after each milking. This cow dried up in a few months. Others are erratic in their response to milking, letting down their milk completely at infrequent intervals. In these types there is usually not a good milker-cow relationship. One such cow for instance produced 4,413 pounds of milk in 305 days in the best of three lactations when milked by the regular herd milkers. In all three lactations there was a great variation from milking to milking with a steep slope in the lactation curve. When milked by a milker she liked, the milking to milking variations became small and she produced 7,114 pounds milk in 305 days with other conditions similar to her previous lactations. This is an increase of 61.2 per cent over her best previous performance and which increase is due to the milker who was able to get all of the milk out of the udder.

There are many other reasons why cows are not completely milked out. Undue excitement at milking time, improper stimulation for the let-down of milk, too long an interval between stimulation for let-down and beginning of milking, too slow milking and incomplete withdrawal of the milk that has been let down are all important contributory factors to poor milking. In addition to these there is the consideration of injury to the teat and udder from improper use of the milking force and which injuries are prominent predisposing factors to mastitis. Five rules have been formulated as guides for proper milking as follows:

Rule 1. Avoid excitement of cows either before or during milking. Excitement blocks the response of hormone secretion to the milking stimulus. For the best response the cow must be relaxed and enjoy being milked.

Rule 2. Stimulate let-down about one or two minutes before milking is to begin. The most effective stimulus is a vigorous massage of the teats and lower part of the udder by a cloth taken out of water as hot as the hands will stand—about 125° F. This stimulates both the warmth and touch perceptors in the skin of the teat. Use of a strip cup acts as additional stimulus and opens up the teat meatus. Do not commence milking until the milk has been let down as evidenced by the distention of the teats and lower part of the udder.

Rule 3. In hand milking use the full hand grasp of the teat. Point compression such as digging in with the finger tips or use of the thumb knuckle is likely to injure the sensitive lining on the inside of the teat as well as produce pain to the cow.

In machine milking operate the milker according to the directions of the manufacturer and see that it is in good working order. Poor mechanical condition of milking machines is responsible for much poor milking. Defects that are often found are vacuum pump in bad repair, vacuum

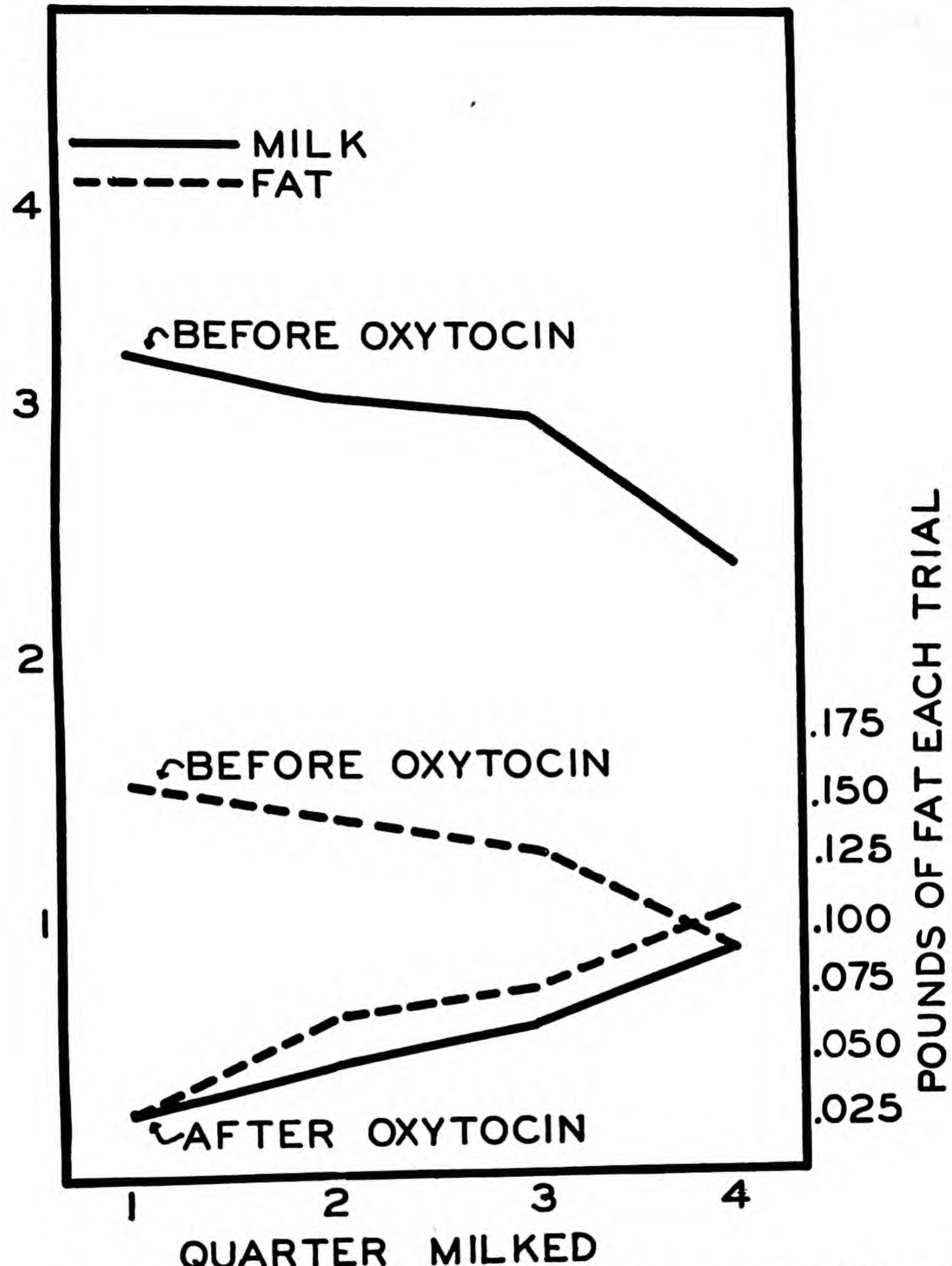


Fig. 86. Delayed milking results in incomplete evacuation of the milk. Each quarter was milked in succession. Note decreased amounts of milk and fat with each successive quarter milked and a corresponding increase following the administration of oxytocin.

gauge out of order, dirt in the pipeline, leaks in air tubes or stall cocks, and broken or distorted inflations.

Rule 4. Begin stripping as soon as the teat cups crawl upward. This is done by pulling the teat cups downward as far as is possible with dropping

off with one hand and successively massaging each quarter with the other hand. Very few cows cannot be completely milked out this way in less time than it takes for hand stripping. In hand milking, milk as rapidly as possible and avoid prolonged stripping.

Rule 5. Remove the milking machine as soon as the milk stops flowing. Failure to do this is responsible for much injury to the inside of the teats as at this point negative pressure enters the teat with damaging effect.

When cows are milked according to these directions, the following benefits are obtained:

1. Time is saved. In average herds not over three and one-half minutes per cow should be required as an average. Great variation in cows should be noted. Some cows milk out in as little as one and one-half minutes while others may require more than ten minutes.
2. Increased milk production will result mainly by improving the persistency.
3. There will be less mastitis because of reduced teat injuries.
4. Cleaner and better milk will result from avoiding extra contamination from hand stripping and reducing the incidence of mastitis.

Order in stall milking. It has been found that the best method is to establish a definite routine and follow it closely. The first essential is that of having all of the equipment conveniently placed. A satisfactory solution is the use of a platform cart having room for the milking machines, pails for the warm water, and a solution for dipping of teat cups, container for used cloths, and at least two cans. The cart should also be provided with suitable facilities for the daily milk sheets and scales for weighing the milk. It is important that the operator of milking machines be in a position where he can view the machines at all times and that his time is available for the attention to the milking job and not spent in carrying milk and going for various equipment to be used.

The following routine affords most efficient use of time and effort when a milker operates two units:

1. Wash, stimulate, and strip cup, No. 1 cow.
2. Wash, stimulate, and strip cup, No. 2 cow.
3. Attach milker unit to No. 1.
4. Attach milker unit to No. 2.
5. Wash, stimulate, and strip cup, No. 3.
6. Strip No. 1.
7. Attach unit to No. 3.
8. Wash, and stimulate, No. 4.
9. Strip No. 2.
10. Attach unit to No. 4, etc.

This routine requires a stall cock for each stall and a transfer pail be used. By use of a transfer pail the milking machine head is transferred to the empty pail while a cover is placed over the one containing the milk. The machine can thus be attached to the next cow without loss of time and the milk cared for later. Two units is the most that any operator can use efficiently. Many operators should use only one unit.

Chapter 36

RECORD KEEPING

IMPORTANCE. ONE OF THE FIRST ESSENTIALS FOR THE INTELLIGENT management of a dairy herd is the keeping of adequate records. No other farm enterprise lends itself so well to record keeping as does the dairy. Individual records should be kept for each cow, and there are excellent means developed for keeping milk and feed records. One of the chief criticisms of the ordinary dairy farm is the failure to keep records in any form, particularly the individual production record. Intelligent selection of individuals to be retained and the formulation of a sound breeding program are entirely dependent upon keeping records and making the proper analysis of them.

Marking cattle. It is necessary that an animal be definitely identified by some mark before other records can be of value. Immediately after birth, an animal should be given a herd number. This number should be recorded in the permanent herd record book, together with specific identification of the animal to which the number belongs. A sketch of the color markings forms an adequate means of identification of broken colored individuals. This system is particularly applicable to individuals belonging to the Holstein, Guernsey, and Ayrshire breeds. Solid colored animals, however, must be identified by some other means of marking, of which there are a number of systems to choose from. A number or symbol may be tattooed in the ear by the proper tattooing instrument and ink. This method is sometimes objected to on the score that difficulty is experienced in reading the tattoo marks on animals with dark skins, and that, in any event, the animals must be caught before the mark can be examined. Ear tags of various shapes with the appropriate identifying numbers are used extensively. Because the ear tag is of necessity limited as to size, it also is objected to because animals must be caught in order to ascertain the identification number. Ear tags also are frequently lost; they often cause irritation in the ear, and are torn out when the animals rub against objects to soothe the irritation. (Fig. 87.)

Another means is to strap the identification tag around the neck. The tag may be of such size that the number can be ascertained without actually catching the animal. However, the strap may wear out or break and the identification mark thus lost.

A chain locked around the horns and carrying the identification tag is a method used by a number of breeders. In herds where the animals are dehorned, this system obviously cannot be used. Furthermore, it is more expensive than some of the other means of identification.

Branding, which is commonly resorted to as a means of identifying range animals, is occasionally used in the identification of dairy animals.

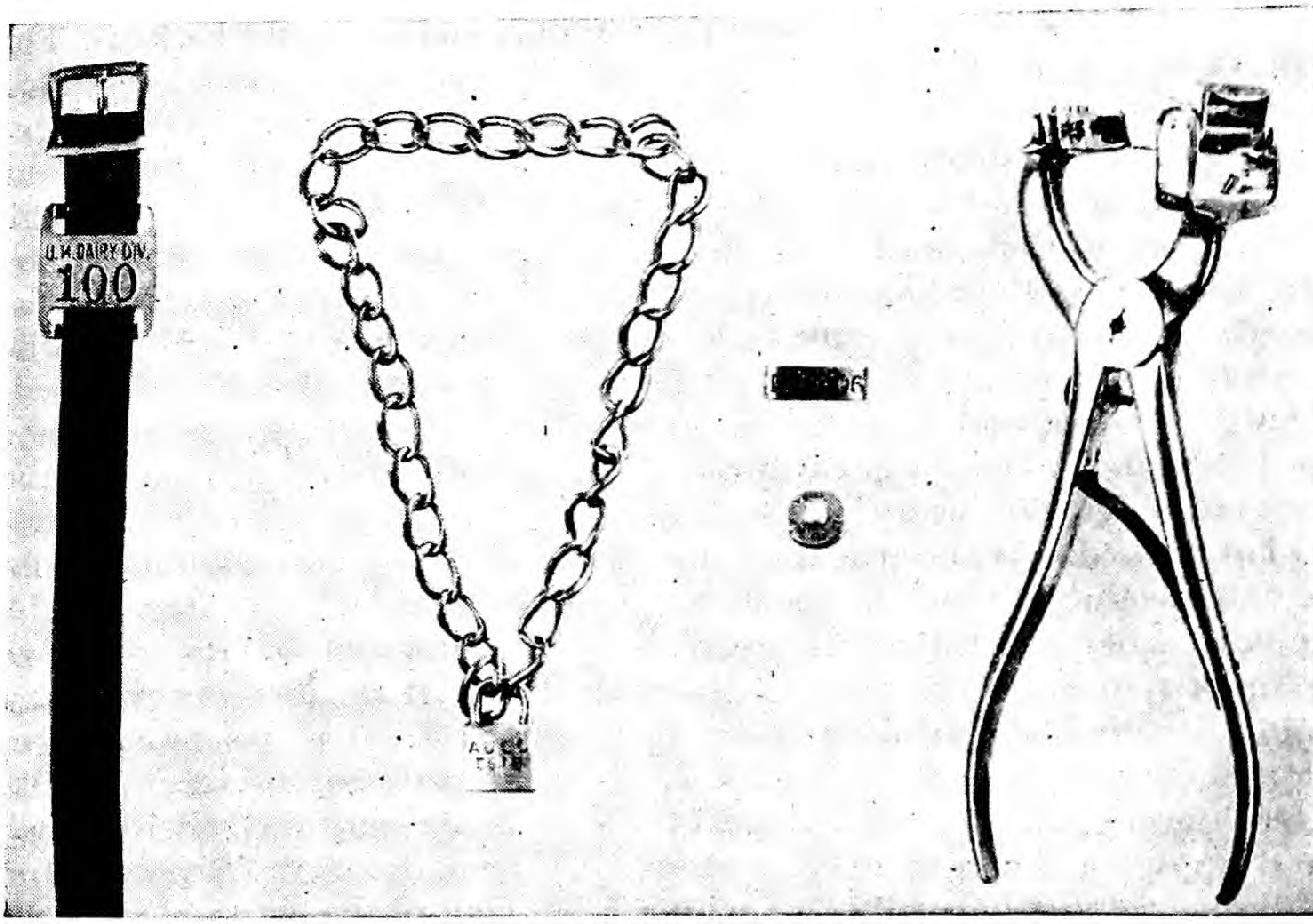


Fig 87. Different types of ear tags, horn chain, and neck strap for identification of cattle are pictured here.

Numbers may be branded on the horn, the hoof, or on the side of the body. This has the advantage of being easily discernible, but it is objected to by many because it disfigures the animal.

As no two animals have the same nose pattern, nose prints may be used as a means of positive identification. The print is taken by rubbing the nose with an ordinary stamp pad and then pressing print paper against the nose. This system meets with the objection that to identify the animal, it must be caught and the nose print taken and compared with the original print.

Herd numbers. While all purebred cows must be named in order to be recorded, and while there may be good reasons for naming other than purebred cows, record keeping is greatly facilitated by assigning numbers to all cows. Also, when one becomes accustomed to the practice, it is just as easy to know and refer to an animal by number as by name.

Milk record. The extreme variation between the milk production of individual cows is five times as great as the variation in fat percentage, and within any one breed the variation is even greater. To evaluate a cow it is, therefore, of much greater importance to know her milk producing ability than to know the fat percentage of her milk. The milk yield for a year may be fairly closely estimated from one- or two-day weighings once a month, or once every two months, for example, or the actual yield may be determined by summation of daily weighings.

There are many reasons why daily milk weights should be kept. The total yearly milk yield can be accurately ascertained, whereas occasional weighings give only an approximation. The record of daily milk weights furnishes the manager information necessary to ascertain whether the cow is doing as well as she should, and if the milker does a thorough job. Drops in daily milk yield due to different factors may be noted by an inspection of the milk sheet, where daily weights are recorded. Discovery of drops in the milk yield may lead to the early finding of the causative factors and their correction before any serious damage is done. Daily weighing and recording of milk is the best check on the efficiency of the milkers. It also adds interest to the work, particularly when the cows are high producers.

Fat record. While it is more important to know the amount of milk a cow produces, it is also necessary to know the fat percentage of the milk in order to estimate the value. The determination of fat percentage of milk requires more time and technical skill than does the weighing and recording of the milk yields. For this reason, it is not practical to determine the fat content of milk as frequently as it is to weigh the milk. Determining the fat percentage of the milk for one day each month and applying the percentage so found to the monthly milk production will give results that will come within 5 per cent of the actual. While the fat percentage of milk may vary considerably from day to day, the chances are that the monthly tests will show that the low tests for some months are counterbalanced by high tests for other months. Samples taken bimonthly are less accurate than monthly samples but are satisfactory if monthly tests cannot be secured.

After the average fat percentage has been found for one complete lactation period of a cow, this percentage can be used for determining the fat production for any subsequent lactation period where the milk weights are known. Turner, studying Guernsey records, found that for 35 per cent of the cases the first and subsequent tests were the same; another 47 per cent varied less than 0.25 per cent in test; and about one-half of 1 per cent varied as much as 1.0 in fat percentage.

The milk sheet. The first requisite to proper milk record keeping is a barn milk sheet and milk scales. The proper equipment and convenient arrangement will do much toward making record keeping a pleasure rather than a drudgery. For this reason it is important to have the milk sheet properly made out and conveniently located. The milk sheet should be located near the place where the milk is emptied, and the scale should be conveniently suspended next to the milk sheet. The spaces for recording the milk weights should be large enough to facilitate making legible figures. A satisfactory milk sheet is reproduced in Figure 88.

During fly season it is necessary to protect the milk sheet from flies. This may be accomplished by covering the sheet with an oilcloth or, better yet, by constructing a glass front case with but an inch of the milk sheet exposed along the lower edge for recording the weights (see Fig. 88). The milk sheet is protected below the glass by a wooden cover, from which

it is advanced up into the glass front case as daily recordings are made. At the end of the month the entire milk sheet has been advanced into the glass compartment and all recordings are visible through the glass.

Because of their convenience only regular milk scales should be used. (Fig. 89.) These are spring balances with dial faces weighing to .1 pound. They also possess a second indicator which can be adjusted to zero for an empty pail. With this type of scale and the milk sheet conveniently located, a milking may be quickly weighed and recorded.

The barn book. The herd book, for various reasons, cannot be kept in the barn. Another book, one that is cheap, should be kept in the barn, and into it should be entered all facts necessary for the record of the herd. These notations may be made chronologically. Breeding dates, calving dates, record of the bull to which a cow is bred, and all other items of importance, such as sickness, date of drying-off, etc., should be recorded in the barn book. Periodically the notes in the barn book should be transferred to the permanent herd book.

The permanent herd book. To be of value records must be in such a

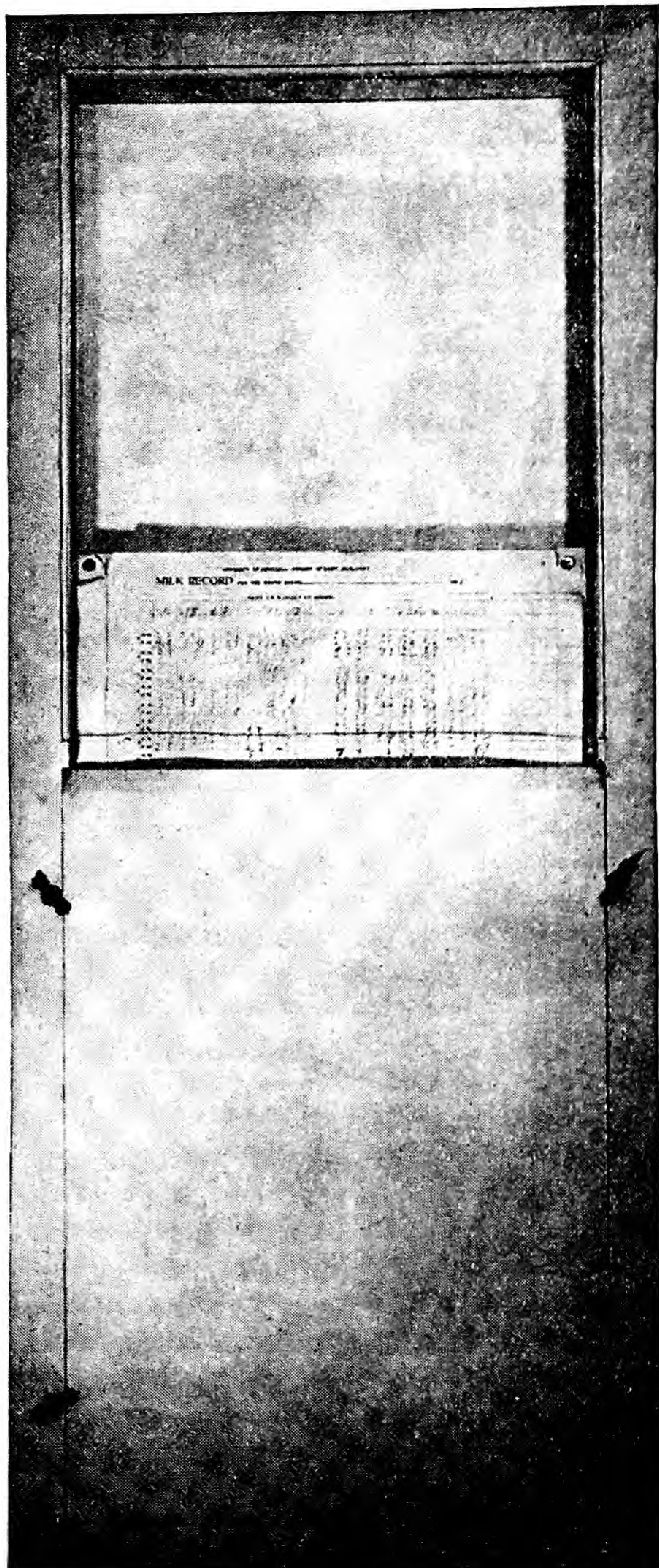


Fig. 88. A milk sheet protected from flies and dirt by glass except for one line for writing. The milk sheet is raised from below.

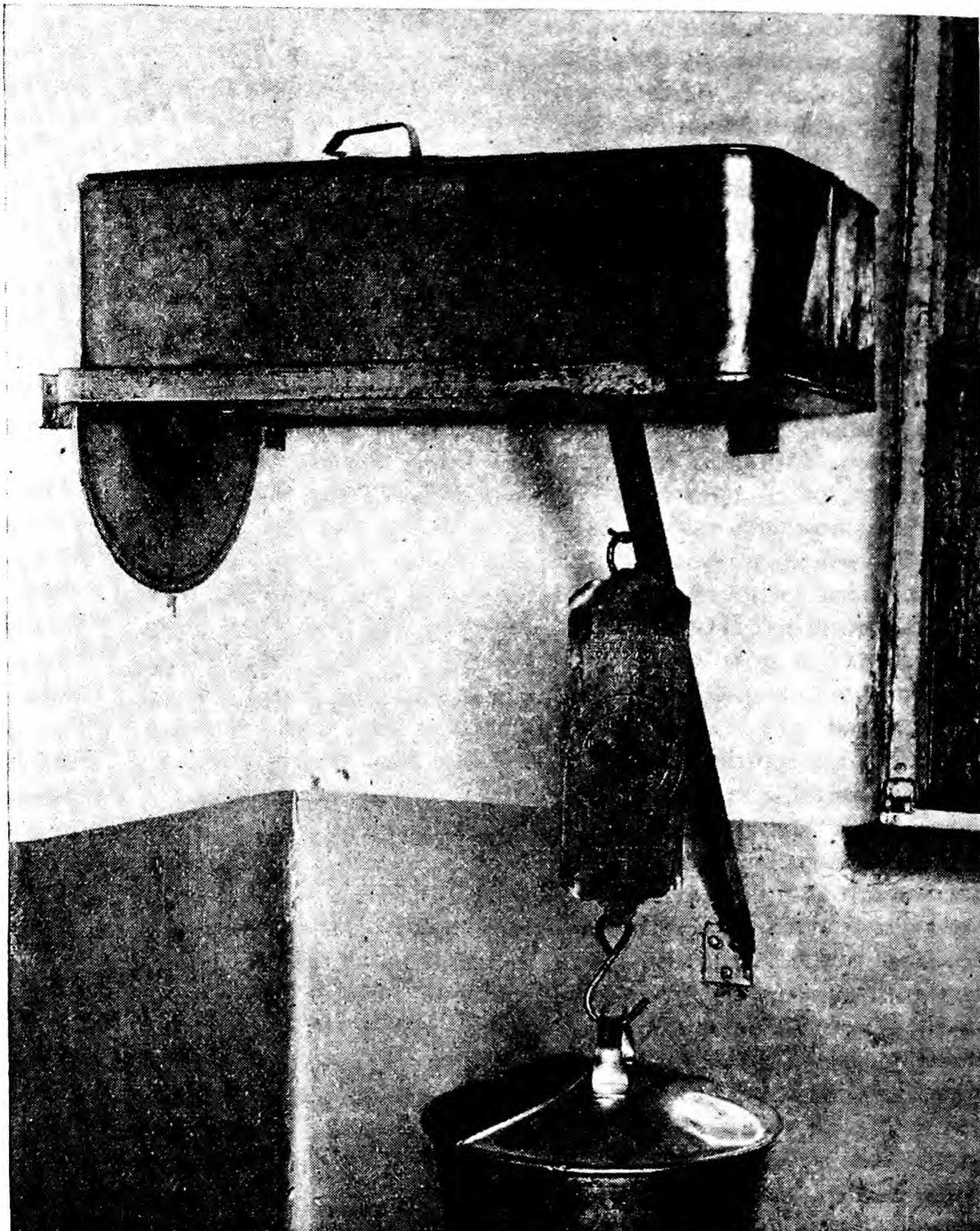
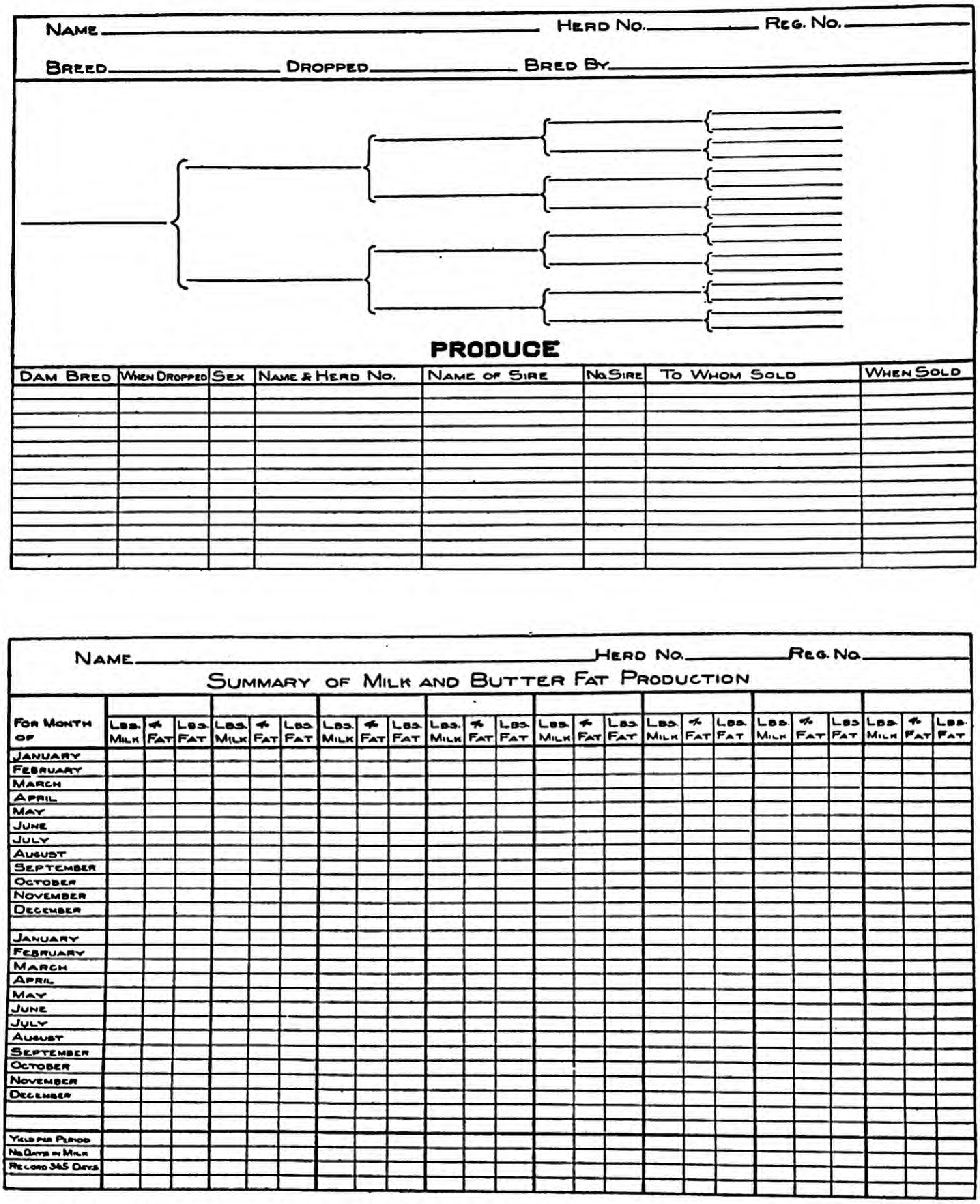


Fig. 89. Good management requires milk scales conveniently located for daily weighing of the milk.

form that they are easily accessible at any time. It is therefore important that all the essential records of the herd be kept in one book and in such a form as to be easily found. There are many different forms that will prove satisfactory. One form, used by the University of Minnesota, is a loose leaf book which has one sheet for the complete life record of the individual. (Fig. 90.) In addition to containing the proper blanks for



NAME ______ HERD NO. ______ REG. NO. ______

BREED ______ DROPPED ______ BRED BY ______

PRODUCE

DAM BRED	WHEN DROPPED	SEX	NAME & HERD NO.	NAME OF SIRE	NO. SIRE	TO WHOM SOLD	WHEN SOLD

NAME ______ HERD NO. ______ REG. NO. ______

SUMMARY OF MILK AND BUTTER FAT PRODUCTION

FOR MONTH OF	LBS. MILK	% FAT	LBS. FAT	LBS. MILK	% FAT	LBS. FAT	LBS. MILK	% FAT	LBS. FAT	LBS. MILK	% FAT	LBS. FAT	LBS. MILK	% FAT	LBS. FAT	LBS. MILK	% FAT	LBS. FAT	LBS. MILK	% FAT	LBS. FAT	LBS. MILK	% FAT	LBS. FAT
JANUARY																								
FEBRUARY																								
MARCH																								
APRIL																								
MAY																								
JUNE																								
JULY																								
AUGUST																								
SEPTEMBER																								
OCTOBER																								
NOVEMBER																								
DECEMBER																								
JANUARY																								
FEBRUARY																								
MARCH																								
APRIL																								
MAY																								
JUNE																								
JULY																								
AUGUST																								
SEPTEMBER																								
OCTOBER																								
NOVEMBER																								
DECEMBER																								
YIELD PER PERIOD																								
NO. DAYS IN MILK																								
RECORD 365 DAYS																								

Fig. 90. The front (*above*) and back (*below*) sides of the permanent herd record sheet used at the University of Minnesota.

the name and number of the cow, one side also contains blanks for the pedigree and for recording the date of birth, the sire, and the disposition of the calves. Inspection of this page will give one the inheritance of the individual, the number of calves she has produced, and the regularity with which she produced them, and also a record of the disposition of the calves.

On the other side are the blanks for the production records by months. The months of the year are repeated twice for each column, permitting the placing of one lactation period in a column, regardless of the time of the year at which it was started. Should an individual live and reproduce for a greater number of years than there are blanks for the production records, another sheet may be inserted. In the average herd this will seldom be necessary.

Using herd numbers and, in general, identifying the cows by means of herd numbers will greatly facilitate making and using the records. When all cows have herd numbers, records are kept in numerical order. Assigning herd numbers to the heifer calves as recorded on the first side of the herd book sheet will facilitate looking up the records of the daughters.

Methods and extent of record keeping. While the keeping of production records is essential to intelligent and efficient management, it is estimated that less than 3 per cent of the cows in the United States have production records. There are a number of systems of record keeping open to use by the dairymen. Records may be kept privately, by Cow Testing Associations when they can be organized, or by mail order testing when it is available. All breeders of purebred dairy cattle have available the facilities for Official Testing or Herd Testing. Each of these systems will be discussed briefly.

Private record keeping. Anyone with the inclination to do so can keep production records on his cows. Samples for the determination of the fat content can be tested at home, or they may be taken to creameries where they will be tested for a small fee. There is one main difficulty, however, which accounts for so few private records being completed: often when samples should be taken and tested, other farm work interferes, and the result is that several months may elapse without fat tests being made and thus the records are incomplete.

Dairy Herd Improvement Associations. The first cow testing association in the United States was started in 1905 in Newaygo County, Michigan. Since then these associations have increased until the peak of 1,143 associations was reached in 1930. During the depression the number of associations decreased to 793 in 1934. The numbers are again on an increase. The Cow Testing Association, now known as the Dairy Herd Improvement Association, is a co-operative association and consists typically of 26 dairymen employing a man known as the tester for keeping the records. The tester visits each herd once a month, spending one day at each farm, usually arriving in the evening. He weighs and samples the milk of that evening and the following morning, taking composite samples of the two milkings for fat determination. The fat percentage of the milk is ascertained by the Babcock test. The amount of milk by the month is usually estimated from the day's production multiplied by the number of days of the month; or when daily milk weights are kept, they may in some cases be summated. By applying the fat percentage to the weight of the milk produced the total fat for the month is estimated. These

HERD PRODUCTION RECORD

YEAR ____________

NAME OR NO ▸	Betty		101		102		103		104		
MONTH and DAY	MILK PER DAY	MILK PER MONTH	MILK PER DAY	MILK PER MONTH	MILK PER DAY	MILK PER MONTH	MILK PER DAY	MILK PER MONTH	MILK PER DAY	MILK PER MONTH	MILK PER DAY
JAN. 15 A. M. P. M. TOTAL	15.2 14.5 29.7	920.7									
FEB. 14 A. M. P. M. TOTAL	14.5 14.0 28.5	798.0 1718.7									
MAR. 15 A. M. P. M. TOTAL											
APR. 15 A. M. P. M. TOTAL											
MAY 15 A. M. P. M. TOTAL											
JUNE 15 A. M. P. M. TOTAL											
JULY 15 A. M. P. M. TOTAL											
AUG. 15 A. M. P. M. TOTAL											
SEPT. 15 A. M. P. M. TOTAL											
OCT. 15 A. M. P. M. TOTAL											
NOV. 15 A. M. P. M. TOTAL											
DEC. 15 A. M. P. M. TOTAL											
CALVED BRED DUE DRY-OFF											

Fig. 91. A simple blank for keeping milk records. The monthly production may be estimatd from computation of weighings for one day. Running totals are easily made.

figures are then entered in the Dairy Herd Improvement Association Herd Book.

In addition to the milk and fat records, the amounts of feed consumed and cost thereof are also estimated. At the end of the 12-month period the whole is totaled. The milk and butterfat production, with the total value

thereof, are credited on one side of the book, while the amounts of feed and feed costs are charged on the other side; and from these figures the income above feed costs is determined.

The chief advantages of a cow testing association are as follows:

1. Such an association assures that the record is kept. When the owner attempts to keep records, he will frequently find that on the day set aside for testing and record keeping, some urgent matters will unexpectedly arise to interfere, and no record will be made.

2. It permits the owner to know not only what the animal in question produces, but also the costs, and furnishes a basis for the intelligent elimination of surplus animals from the herd. The elimination of the lower producers in the average herd usually does more than anything else in raising the herd averages.

3. Since the records are kept by a disinterested party, they have a greater commercial value than private records, although those instrumental in the promotion of Dairy Herd Improvement Associations do not wish to emphasize the commercial value of the record.

4. The greatest value from belonging to a Dairy Herd Improvement Association comes in the information and help received from the tester in regard to feeding, herd management, and crop planning. More often than not, the tester will find that the good cows are underfed and the poor cows are overfed. Rearrangement of the rations as recommended by testers has been instrumental in raising the production of Dairy Herd Improvement Association herds. Frequently, too, the tester has discovered that while enough feed is given the cows, the ration is deficient in protein; and when a small amount of high protein food was added to the ration, large increases in production were effected.

The following table illustrates how production per cow per year increased with successive years of Dairy Herd Improvement Association testing. This was accomplished, according to the owner, by eliminating the poorer animals from the herd as indicated by the tester's record and by selecting the calves from the higher producing animals.

Being a member of a Dairy Herd Improvement Association is a mark of distinction. In 1946 the average production per cow in a Dairy Herd Improvement Association is 349 pounds of fat and 8,635 pounds of milk, while the average for the United States is about 4,800 pounds of milk and 172 pounds of fat. There are two main reasons for the high average production of cows in Cow Testing Associations: first, the work of the Dairy Herd Improvement Association teaches one to practice more rigid culling of poor producers and to use better production methods—all of which results in higher production; and second, the better dairymen take advantage of the opportunities offered in an association and become members of it.

Recently there has been a modification of the standard Dairy Herd Improvement Association, in which tests may be conducted bimonthly instead of monthly. The only difference is in the number of tests conducted

and the somewhat lessened accuracy of the records. The bimonthly associations can accommodate twice the number.

Official Testing. Official Testing has already been discussed under each of the breeds as it relates to the particular breed under discussion, but a general discussion of Official Testing is appropos at this point. The Official Test system was developed by the breed associations for the breeders of purebred cattle and started, as has already been noted, before the introduction of the Babcock test. At first it was confined to seven-day records, made for milk and butter—the butter being ascertained

RESULTS OF 11 YEARS OF TESTING IN A COW TESTING ASSOCIATION [1]

Note the progressive increase up to 1935 and 1936. Poor feed conditions of 1935 and 1936 are responsible for the lower production.

Year	Cows	Milk	Fat	Fat
	Number	*Pounds*	*Per Cent*	*Pounds*
1926	22.47	6,373	5.4	343.7
1927	27.44	6,898	5.27	359.7
1928	27.00	6,890	5.38	371.2
1929	28.00	7,004	5.39	377.7
1930	29.25	7,315	5.27	386.0
1931	36.08	7,282	5.43	395.7
1932	28.6	7,821	5.40	422.3
1933	28.83	8,777	5.40	475.6
1934	27.94	8,807	5.48	482.2
1935	32.05	6,644	5.63	373.96
1936	32.68	7,882	5.26	414.79

by actual churnings. Later on this was extended to yearly testing, and rules and regulations were adopted to safeguard the accuracy of the records, which were highly commercialized. The Official Tests are supervised by a representative of the agricultural college in each state. This representative is known as the Superintendent of Official Testing. He appoints the test supervisors who inspect and conduct the tests on the farms. All reports are sent to the offices of the various breed associations, where they are tabulated and published and certificates are issued.

There are two essential forms of Official Testing: one known as official and the other as semiofficial testing.

The official testing referred to is that type of record in which an official inspector supervises the entire record period, whether it be seven days or a year in length, taking and testing samples of each milking. This form was too expensive for long-time records, and the short-time records have been found to be of so little value that, in the main, they have either been discontinued by the breed associations or are little used by the breeders.

[1] ASTROTH, F. B.

The semiofficial testing is a long-time testing of 365 days and of not less than 305 days. In this form the inspector supervises milkings at intervals; the milk is weighed, sampled, and tested. The owner keeps daily milk weights. At one time, a two days' inspection period each month was required. This has now been modified so that one day each month or two days, bimonthly, may be elected. The amounts of milk found by the inspector are checked against the owner's report of milk weights, and the fat percentage as ascertained by the inspector is applied to the milk weights reported by the owner in the interim between inspection periods. That the supervision in the conducting of these tests is most careful is shown by the fact that a preliminary dry milking for each inspection period is required. The inspector ascertains that the cow is milked dry, and then the last milking period must be 24 hours or 48 hours, as the case may be, from the dry milking time. The inspector also must watch the milker while he is milking and take charge of the milk immediately after milking to avoid the possibility of additions being made to the milk. The owner may elect to test any or as many of the cows of his herd as he desires. Usually a limited number that have been properly fitted are selected for official testing. Those who can afford it engage expert test cow milkers, feed the cows to produce the maximum that they are capable of, and milk them four times a day. In recent years this system of forcing cows for record making has been severely criticized as being unnatural and not representing the true value of the animal. The chief criticism, however, lies in the fact that only a few animals are tested, and that those animals which are known to be incapable of producing a favorable record are not tested. Through the selection of a few of the best daughters of a bull for testing, a reputation as a sire of high production may be established when only a small percentage of his daughters are really good producers. The system of forced feeding, four times a day milking, and rigid supervision of the test has much to commend it. Only in this way can the maximum producing capacity of a cow be determined.

Herd Tests. Recognizing the shortcomings of the Official Test in permitting the selection of the better cows for testing, a number of breed associations have established a system known as the Herd Test. The Herd Test system differs from the Official Test mainly in requiring that all milking animals in the herd must be entered on the test. Like the Official Test, this system is limited to the use of breeders of purebred cattle. It permits milking four times a day, forced feeding, and that animals may be entered in both the Herd Test and the Official Test. If on Official Test, those animals so entered must be supervised according to the rules governing those tests. Different breed associations have slightly different forms for reporting the results. In some cases, only herd averages are reported, and in others, individual cow certificates are given for either the calendar year or the lactation year, as the case may be.

Owner-sampler testing. For those who do not wish to pay the costs of Dairy Herd Improvement Association testing or are unable to obtain

such services there are provisions in many communities whereby records of production may be obtained by what is known as owner-sampler testing. In these cases the owner must weigh the milk at least once monthly and take a composite sample of a day's milk similarly to the tester. This sample is taken or sent to a laboratory where the butterfat content is determined and in many cases, if accompanied with the day's milk, weight computations of the milk and butterfat production for the month will be made. In some cases the owner is instructed just before the sample is to be taken and someone then picks it up.

Keeping milk records only. While it is important to know both the quantity of the milk and its fat content it is more important to know the amount of milk than the percentage of butterfat it contains—because amounts of milk is subject to much greater variations than fat percentage. Knowing the amount of milk a cow produces and then applying the fat percentage representative for the breed, a reasonable estimate of the total butterfat production can be made. If an occasional test of the milk is made as a basis for the fat percentage used the estimate will be more representative of the actual production.

By weighing the milk one day each month and multiplying the total day's production by the number of days in the month a reasonable estimate of the month's production can be made. A suggested form for recording the day's weights provisions for entering the monthly estimates and simple running summary of monthly production is shown in Figure 91.

Chapter 37

EFFICIENCY AND COST OF MILK PRODUCTION

DETERMINING THE COST OF PRODUCING MILK IS ONE OF THE IMPORTANT and at the same time one of the difficult problems connected with dairy farming. The interrelationship between the dairy and the other farm enterprises is such that it becomes difficult to separate the charges that should be made against the dairy from those that should be made against other farm operations. The customary method of expressing as profit the income from the sales of milk and butterfat less the cost of feed consumed, is inaccurate; and it frequently distorts the picture of profits from the dairy cow. Under certain conditions cows with a relatively low income above feed costs may have a lower cost of milk produced than cows with larger returns over feed costs.

The cost of producing milk or butterfat varies greatly from time to time with different farm conditions. Average figures have been worked out and will be presented later in this discussion. Such figures serve only as a guide and cannot be used indiscriminately in arriving at milk production costs. The general factors entering into the cost of producing milk hold true almost everywhere. A consideration of these factors is important in the proper approach to the problem of calculating the cost of production. The costs may be distributed under the following heads:

1. Cost of feed
2. Cost of labor
3. Cost of herd sire
4. Investment
5. Depreciation
6. Miscellaneous costs

In order to get at the net cost of producing milk, all the costs must be considered, and credit must be given for the calf and the manure.

Feed cost.[1] Feed constitutes, in the main, the largest single item of expense in producing milk. It is also one of the most variable items in cost, depending upon the kinds of feed used, the market condition, and the utilization by the cow. The feed cost varies from as low as 50 per cent to as high as 75 per cent of the total cost of producing milk.

Coefficient of Efficiency, and fat-corrected milk. One of the most important factors in lowering the cost of milk production is the efficiency of the cow in returning nutrients of the feed consumed in the milk she produces. The percentage of the digestible nutrients of the feed returned in the milk is known as the Coefficient of Efficiency. A formula for calculating the

[1] On the basis of the high prices prevailing in 1948 all costs for feed, labor, etc., are about 100 per cent above those figures given in this chapter. Credits likewise are increased by the same figure.

Coefficient of Efficiency has been devised by Gaines.[1] The milk first is converted into an equivalent of 4 per cent milk, known as fat-corrected milk (F.C.M.). The formula is:

$$\text{F.C.M.} = .4 \times \text{yearly milk production} + 15 \times \text{yearly fat production}$$

One pound of fat-corrected milk contains .172 pounds of digestible nutrients and requires, according to the Haecker Standard, .327 pounds of the total digestible nutrients in the feed. One pound of animal live weight requires 2.893 pounds of total digestible nutrients for maintenance for one year. The formula [2] for the Coefficient of Efficiency (C.E.) is developed as follows:

$$100 \frac{.172 \times (\text{F.C.M.})}{2.893\text{W} + .327 \times (\text{F.C.M.})}$$

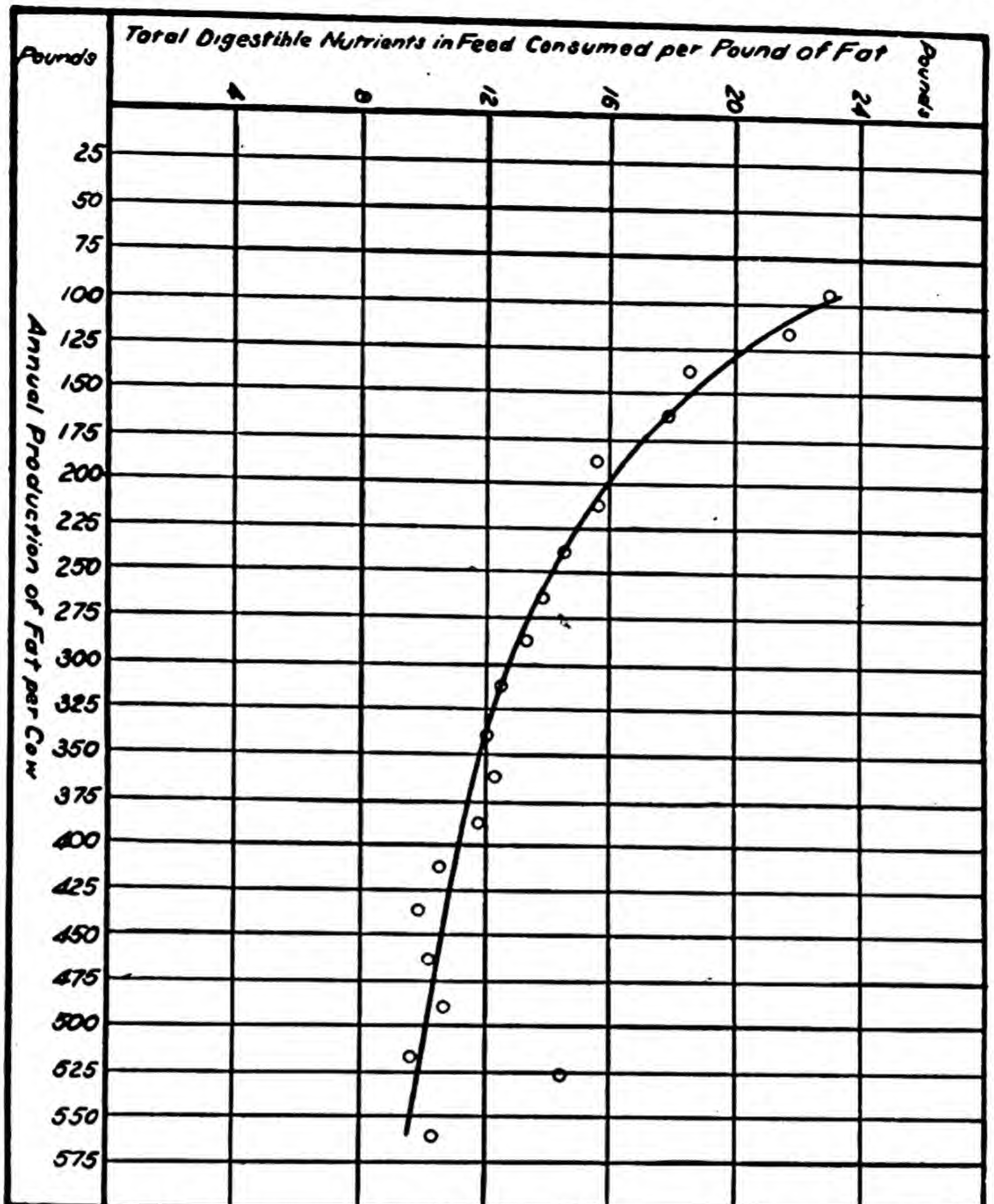
Dividing by .327 and transposing:

$$(\text{C.E.}) = 52.6 \frac{(\text{F.C.M.})}{(\text{F.C.M.}) + 8.847\text{W}}$$

It is evident that increase in production enlarges and increase in weight decreases the Coefficient of Efficiency. A cow weighing 913 pounds and producing 6,657 pounds of F.C.M. has the same C.E. as a 1,021 pound cow producing 7,458 pounds F.C.M. Each one has a C.E. of 23.8. A 1,200 pound cow producing 6,657 pounds of F.C.M. has a C.E. of 20.3, as compared to a C.E. of 23.8 for a 913 pound cow producing the same amount of milk. When the 1,200 pound cow produces 15,000 pounds of F.C.M. her C.E. becomes 30.8, or the milk produced contains 30.8 per cent of the total digestible nutrients in the feed consumed.

It is evident that the feed cost per unit of milk decreases with the increased production of the cows, provided that the additional feed required to produce the larger amounts of milk is not too expensive. When roughages are much lower in price than concentrates, a condition may exist where lower milk production secured on roughage alone costs less than higher production on rations where a larger proportion of the ration consists of concentrates. The United States Department of Agriculture [3] observed that for conditions existing in Montana, alfalfa, as the sole ration for dairy cows, produced only 70 per cent as much milk as was produced with a liberal grain allowance, but at a lower cost. The addition of a limited amount of grain made the most economical production of milk and butterfat. (See the section in Chapter 43 called *Feeding cows on limited quantities of concentrates.*) The large number of studies of the relationship between costs and levels of production will be used to further illustrate this relationship. Results of studies in Illinois [4] showing a steady decrease in the nutrients required to produce one pound of butterfat with increases

[1] GAINES. Science 67:353. 1928.
[2] W = Live weight of the cow.
[3] U. S. Dept. Agr. mimeographed material.
[4] ROSS, HALL, AND RHODE. Ill. Agr. Expt. Sta. Bul. 244. 1923



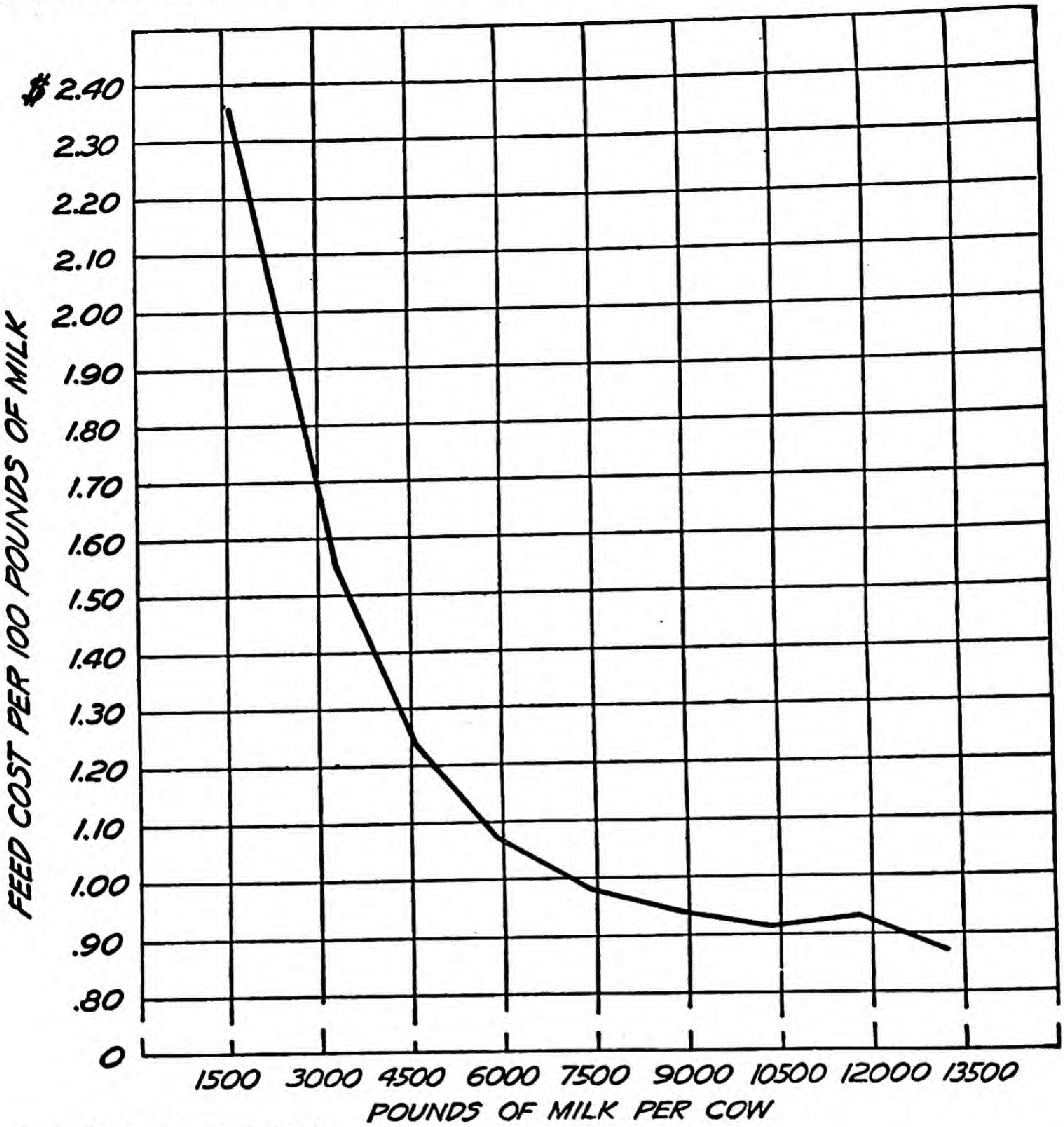
Ill. Bul. 244

Fig. 92. Showing the decrease in pounds of digestible nutrients required per pound of butterfat with increasing annual milk production.

in annual production are reproduced in Figure 92. Cows producing 100 pounds of butterfat annually required approximately 23 pounds of digestible nutrients per pound of butterfat, while cows producing 500 pounds of fat annually required but ten pounds of digestible nutrients per pound of fat.

The extensive studies of Dairy Herd Testing Association reports made by McDowell [1] furnish further evidence of lowered feed cost per unit of milk or butterfat with increasing production. The relationship between the annual milk production and the feed cost per 100 pounds of milk is shown in Figure 93. It is to be noted that in the lower production range each increment in milk production is accompanied by a large decrease in feed cost per 100 pounds of milk. The advantages from each increment

[1] McDowell. U. S. Dept. Agr. Bul. 1069. 1922.



U. S. Dept. Agr. Bul. 1069

Fig. 93. Showing the decrease in the cost of 100 pounds of milk with increasing annual milk yields.

in production become less until 9,000 pounds is reached, when further increases in production do not decrease costs per unit of milk.

When very high producing cows are fed heavily upon high priced concentrates, milk production is usually made at increased feed costs. Besides the high cost of the concentrates used under these conditions an excess of nutrients are fed beyond those required for maintenance and production.

It is apparent that when each additional unit is produced at increasing cost, the law of diminishing returns functions in the production of milk. At exactly what point this starts is not known as it varies for different conditions. In Figure 93 it is apparent that feed costs per 100 pounds of

milk are not materially reduced after a yearly production of 8,000 pounds of milk is reached. Other than feed costs also increase for higher production.

Amount of feed required to produce milk. The amount of feed required to produce 100 pounds of milk varies widely with the size of the cow, the amount of milk she produces, and the kind of feed she is given. A 1,000 pound cow needs at least 2,600 pounds of total digestible nutrients annually for maintenance. This is equivalent to approximately 5,200 pounds of hay. For each 1,000 pounds produced, an additional 335 pounds of total digestible nutrients are required. This amount represents about 670 pounds of hay or 450 pounds of good concentrate mixture. The following table shows the amount of hay and the concentrates required for varying production levels of a 1,000 pound cow producing 4 per cent fat milk.

AMOUNTS OF HAY AND CONCENTRATES REQUIRED TO PRODUCE 100 POUNDS OF MILK AT VARIOUS LEVELS OF PRODUCTION

ANNUAL MILK PRODUCTION	FEED REQUIRED PER YEAR		FEED PER 100 POUNDS OF MILK	
	Hay	Concentrates	Hay	Concentrates
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1,000	5,870	—	587	—
3,000	7,210	—	260	—
5,000	7,210	900	144	12.0
7,000	7,210	1,800	103	25.7
10,000	7,210	3,150	72	31.5
15,000	5,870	6,300	39	42.0

These figures are calculated from the requirements according to the revised Haecker Feeding Standard. Silage may replace varying amounts of hay provided that three pounds of silage are supplied for each pound of hay replaced. If good pasture is supplied, it may replace as much as 40 per cent of the feed in the North and up to 75 per cent in the South.

Labor costs. Labor represents the next largest single item of expense in producing milk. Labor costs vary greatly, depending upon the production level of the cows, the cost of the efficiency of the labor, and the conveniences for work. On an average, labor represents about 20 per cent of the total cost of producing milk. The largest single item of labor is represented by milking. Misner [1] reports that milking requires 53.6 per cent of all labor incident to producing milk. This item can be reduced 50 per cent or more by the use of milking machines, although it is partially compensated for by increased investment and depreciation of the milking machine; and one must remember that increased power costs more for operation.

The Illinois Station [2] found that 133.9 hours of labor are required per

[1] MISNER. N. Y. Agr. Expt. Sta. Bul. 409. 1922.
[2] PEARSON AND ROSS. Ill. Agr. Expt. Sta. Bul. 241. 1923.

cow a year when the milking is done by hand, and 81.5 hours when the milking is done by machine. In a study of cost of milk production in Maine,[1] Dow found that with larger herds labor is more efficient. He found that 209 hours of labor were required for each cow per year in smaller herds, and 163 hours per cow in larger herds. Dow also reports an increase in the amount of labor required for high producing cows over poorer cows, but smaller labor costs are required per 100 pounds of milk for the former. The annual cost of labor per cow producing 5,000 to 6,000 pounds of milk was $40.00, while the cost per cow producing over 9,000 pounds of milk was $53.00. The labor cost per 100 pounds of milk was $.71 for the former and $.50 for the latter.

The returns from the dairy may be expressed in returns per hour for labor. Cavert,[2] studying costs of producing butterfat in Minnesota, found a good correlation between the return per hour of labor and the production level of the cows milked. After deducting all expenses and crediting all income, he found the returns for labor varied from 7 cents to 77 cents per hour.

Attention is called to the fact that more labor is required to produce milk for the market than to produce butterfat as cream. More time is required for the care of milk than for the separation; the extra precautions that must be taken in producing high quality market milk requires more labor than does the production of cream to be sold as butterfat.

Cost of the herd sire. The cost of keeping the herd sire is a considerable item of expense. Figures for this are given in Chapter 25. The cost of keeping the herd sire is subject to the same variations due to the same causes as the cost of maintaining milking cows. It is obvious that the sire cost per cow or per 100 pounds of milk decreases with increased herd size.

Interest on investment and depreciation. Two charges that must be made if actual costs of milk production are to be determined are interest on the investment and depreciation. Dairy farming requires rather large investments in building, yards, equipment, and cattle, for which the going rate of interest and a fair depreciation should be charged. The charges to be made for these items per cow or per unit of milk depend upon the amount of the investment for the interest charge, and the type of buildings, equipment, and cattle for depreciation charges.

Buildings and yards. The annual charges against the dairy for buildings include interest, depreciation and repairs, and insurance and taxes. The annual charge per cow for these items vary from as low as $1.00 when cheap sheds are used, up to more than $50.00 per cow, when expensive barns are used. A fair average investment in buildings is between $60.00 and $100.00 per cow in market milk-producing areas of the North, and from $40.00 to $75.00 in butter-producing areas. The interest amounts to about one-half of the total annual building charges.

[1] Dow. Me. Agr. Expt. Sta. Bul. 385. 1936.
[2] Cavert. Minn. Agr. Expt. Sta. Spec. Bul. 112. 1926.

Equipment. Equipment, which consists of such items as drinking cups, salt cups, litter carriers, milking machines, cans, pails, milk cooling equipment, washing equipment, etc., carries the same interest charges as buildings do, but the depreciation and repair charges are greater; they usually average about 10 per cent annually. The charges per cow for these items vary with the size of the herd and the amount of equipment used. In Maine where cows were milked by hand the annual charge was 68 cents per cow; when milking machines were used, the charge per cow was $2.63

The cows. Since cows are introduced into the milking herd either when they are purchased or when they are raised on the farm, they should be inventoried at cost. Annual interest charges should be based upon the inventory values. Cows are sold from the herd as beef when their usefulness is over, and as surplus stock for milk production in some other herd. In addition, 1 to 2 per cent of the cows die while in the herd. Cows sold for beef as a rule bring less than costs; this, together with losses from death, constitutes depreciation. It is difficult to establish actual depreciation for any one year as market values of animals sold for beef vary greatly from year to year.

While the interest charges vary proportionately with the inventory value of cows, the depreciation charges increase more rapidly with increases in the original cost of cows. There is but little relationship between the original cost of a dairy cow and the sales value for beef. This is particularly true of purebred cows, where the original price bears no relationship to the beef values.

The most recent reports show an annual depreciation per cow in one area of $9.75, or 13 per cent of the average value per cow. In another area the average depreciation was $2.81, or 5 per cent of the average value per cow. In another comparison of grades and purebreds the depreciations were $5.00 and $11.00 respectively. The annual depreciation for purebred cows may be very high. A cow costing $500 may be sold for $50, after being in the herd for five years; since five years is the average productive life of a cow, this cow would carry an annual depreciation of $90.

Miscellaneous costs. In addition to the cost items previously discussed there are a number of miscellaneous expenses, such as the costs of water, light, power, bedding, insurance, taxes on the cattle, testing, veterinary services, and various supplies. The costs of these items vary from a few dollars to $15 per cow. Representative figures would run from $5 to $10 per cow.

Credits other than milk and butterfat. After deducting all the items of expense that have been mentioned, there are certain credits that must be made before the cost of either milk or butterfat can be ascertained. Manure, calves, hides from cows that die, and, when butterfat is sold, skim milk are items that have values. From eight to twelve tons of manure and about .9 calf can be expected from each cow annually. Under normal price conditions these will have values of from $20 to $25. When butterfat is sold, the skim milk has feed value ranging from 15 cents to 30 cents per 100 pounds.

Cost of milk production formulas. A number of formulas have been advanced that express the requirements for producing 100 pounds of milk in terms of feed and labor, together with a correction factor in some cases. The requirements of these formulas were arrived at from survey studies of the cost of producing milk and represent average figures. They do not, therefore, apply necessarily to any one herd. Low producing herds will find larger and high producing herds smaller requirements than those expressed in these formulas. The proportion of concentrates to roughages is also subject to great variation. In some cases hay only is fed; in others most of the nutrients come from concentrates.

The two most commonly used formulas are Warren's and Pearson's. Warren's [1] formula for the requirements to produce 100 pounds of milk is as follows:

Concentrates	33.8 pounds
Hay	43.3 pounds
Other roughage	10.8 pounds
Silage	100.5 pounds
Labor	3.0 hours

Add 25 per cent for overhead.

By applying the prevailing prices for the various items the cost of producing 100 pounds of milk may be ascertained by this formula.

Pearson's formula is as follows: [2]

Concentrates	44.0 pounds
Hay	50.0 pounds
Other roughage	39.0 pounds
Silage	188.0 pounds
Labor	2.42 hours

Attention is called to the wide differences in the requirements of these two formulas. The Pearson formula requires more of each of the feeds and less labor. To compensate for the higher feed requirements of the Pearson formula no correction factor for overhead is used.

Seasonal variation in cost of milk production. The cost of producing milk varies with the use of pasture. The variations in the cost of producing 100 pounds of milk are illustrated in the table above, taken from studies in Illinois.[3] For June the cost of milk production is only 55.3 per cent as high as for December. With the decline in the amount of pasture the cost increases because of lowered milk production and increased use of pasture supplements.

The chief reason for low cost of milk production during the spring, summer, and early fall is the much lower cost of feed when secured from pasture. Other costs are essentially the same for all months of the year

[1] WARREN. Cornell Agr. Expt. Sta. Farm Econ. Bul. 42. 1927.
[2] PEARSON. Ill. Agr. Expt. Sta. Bul. 216.
[3] PEARSON. Ill. Agr. Expt. Sta. Bul. 224. 1919.

Seasonal Variation in the Cost of Producing 100 Pounds of Milk

Month	Cost	Per Cent of High Month
November	$2.01	96.6
December	2.08	100.0
January	2.00	96.1
February	2.08	100.0
March	1.93	92.8
April	1.76	84.2
May	1.26	60.6
June	1.15	55.3
July	1.36	65.4
August	1.66	79.8
September	1.66	79.8
October	1.54	74.0
Average	1.73	83.2

except labor. Indiana studies revealed labor requirements for the summer as being about 20 per cent less than for the winter.[1]

Other considerations. While it is important to ascertain the cost of producing milk (and every effort should be put forth to reduce costs) a low margin of income over cost does not necessarily mean that the dairy enterprise is undesirable. When family labor is available and would not otherwise be used, the dairy permits additional farm income even though it be at low wages.

Dairy cattle also make use of crops that are not marketable or would be be marketed at lower prices than can be realized if fed. Careful thought should be given to growing the highest yielding crops that can be utilized by the dairy cattle and the formulation of the most economical rations based upon the use of homegrown feeds.

[1] Bain and Posson. U. S. Dept. Agr. Bul. 858. 1920.

Chapter 38

COMMON DISEASES OF DAIRY COWS

DISEASE IS THE CAUSE OF EXTENSIVE LOSSES TO DAIRYMEN THROUGH THE cost of treatment, the loss in milk production, and the loss of the cows through death or sale for slaughter because of impaired producing capacities. While extensive figures giving the losses from disease are not available, the figures from the Iowa Cow Testing Associations for 1935 and 1936 are probably representative.[1] These figures show that 9.6 per cent for 1935 and 9.7 per cent for 1936 of all milking cows in the Associations were sold because of udder trouble, sterility, Bang's disease, and tuberculosis. In 1935, these diseases accounted for 27 per cent and in 1936 for 31 per cent of all cows sold from these herds. The losses from other diseases and from lowered milk production of diseased cows retained in the herd are unknown, but without question they are extensive.

It is not intended that this discussion shall give instructions for the treatment of diseases of cattle. Because of the importance of disease in the management of dairy cattle, it is desired to emphasize the importance of maintaining a healthy herd, and to briefly discuss the more important diseases. The successful treatment of disease is a highly specialized science, and the services of competent veterinarians must be used in the development of disease symptoms if satisfactory results are to be expected. Too frequently, the services of a veterinarian are not called for until the disease has advanced too far for successful treatment.

The diseases incident to reproduction, udder injuries, nutritional deficiencies, food poisons, and common ailments of calves have been discussed elsewhere in this book. At this juncture the general factors involved in disease prevention and control will be considered, and other important diseases and ailments that are common to dairy cattle will be discussed.

General factors in the prevention and control of diseases. The most important consideration in disease control is that of prevention. After the onset of disease, problems of control and therapy arise which usually call for the services of experts.

In the prevention of disease there are three important factors that are under the control of the herd management. These are (1) general herd sanitation, (2) nutritional status of the herd, and (3) the health of animals brought into the herd.

Cleanliness and sunlight are enemies of disease organisms, while dirty, damp, and dark places are conducive to the preservation and development of microorganisms in general. The first requisites for the maintenance of

[1] Yearly Summary of Cow Testing Associations in Iowa. 1936.

a disease-free herd are clean, dry, well-lighted quarters. Cleanliness must not be confined to the barn; it must be extended to the yards, pastures, and any other places where cows are kept. Good drainage to prevent mud formation and stagnant pools is just as essential as clean barns. It is also essential that the litter pile be inaccessible to the cattle, as organisms from infected animals, which usually contaminate the fecal matter, may survive for long periods of time.

While many infectious diseases attack cattle regardless of the state of nutrition, a well-nourished animal offers greater resistance to infection from many diseases. It has previously been shown that certain vitamin deficiencies increase the susceptibility to infections. The well-nourished animal has greater reserve and may suffer less and recover sooner from disease than animals in a poorer state of nutrition.

From time to time it is necessary to bring new animals into the herd; this also entails the danger of introducing disease. Before animals are purchased and introduced into a herd, they should not only be free from symptoms of disease and negative to the various tests, but special effort should be made to have them come from herds which are free from disease. Further precaution should be taken against introducing disease by isolating newly acquired animals from the rest of the herd for a period of at least 30 days.

After disease has gained entrance into a herd, the manager must take special sanitary precautions to prevent further spreading. At the first sign of any disease symptoms in an animal, it should be isolated from the rest of the herd. Every precaution should be taken against communication between infected and healthy animals, whether direct or indirect—through attendants and from small animals. The liberal use of disinfectants is essential. In the case of certain diseases, infected animals should be eliminated from the herd and the premises thoroughly disinfected before healthy animals are allowed entry.

Treatment of sick animals, as has been previously stated, should be left to the direction of a skilled veterinarian.

Continued testing for tuberculosis and Bang's disease is essential to maintain a herd free from these two devastating diseases.

The medicine cabinet. Every dairy barn should have a medicine cabinet equipped with the following items:

- Clinical thermometer
- Drenching bottle
- Set of milk tubes
- Set of teat plugs
- Syringe (50 cc. hypodermic type is best)
- Trocar
- Cannula
- Mineral oil or Epsom salts
- Tincture of iodine
- Medicated vaseline
- Concentrated hypochloride solution
- Calcium gluconate
- Lysol

B. S. Rahi Snergi

Additional space should be available for medicines that the veterinarian may prescribe. Extensive stocking of medicines is not to be advised as many deteriorate with age. Also, the presence of many medicines in the

cabinet is frequently a temptation to use them, and to use them without skilled advice may do more harm than good.

Giving physics. When an animal loses its appetite for various reasons or becomes "bound" the administration of a physic is advised. Either a pint of mineral oil or one to one and one-half pounds of Epsom salts in two quarts of water may be used. In either case a drenching bottle should be used. In drenching an animal the liquid should be permitted to flow into the gullet by gravity. Place the mouth of the long-necked drenching bottle halfway back in the mouth and on the center of the tongue. Let the liquid run out slowly, stopping frequently to permit swallowing. If the animal coughs, remove the bottle and lower the head to prevent fluid from getting into the lungs. If the latter should happen, it may be the cause of pneumonia.

Brucellosis. Brucellosis, also known as contagious abortion and Bang's disease, after the name of the discoverer of the causative organism, is the cause of greater financial loss to the dairy farmer than any other disease except mastitis. It is caused by a bacterium known as *Brucella abortus*. The disease is found all over the world and is of extreme importance because of the losses incurred by abortions and the fact that the organism will produce a serious disease in man.

In addition to the loss of calves, heavy losses are incurred through the greatly lowered production of aborting cows. Sterility, weakened condition of calves, and mastitis are often associated with brucellosis. Rich found that aborting cows produced 21.7 per cent less and heifers 16.5 per cent less than normal for the lactation in which they aborted.[1] The stage of gestation at which abortion occurred was found to be an important factor in the effect upon production. If abortion occurs in the first three months of gestation, milk production is reduced 37.2 per cent; in the seventh month, 12.4 per cent; and in the ninth month, 10.4 per cent.

Aborting cows have a lower breeding efficiency. In the Minnesota Station herd over a period of 30 years cows that aborted were only 75 per cent as efficient breeders as were nonaborting cows. In another herd the figure is 87 per cent. Eckles [2] reported aborting cows as becoming sterile 16 per cent more frequently than nonaborting cows.

One of the most serious aspects of brucellosis in cattle is that humans are subject to contracting the disease; it is known as brucellosis or undulant fever. Brucellosis in man may be a serious debilitating disease that is resistant to treatment. The disease may be contracted from the consumption of dairy products contaminated with the *Brucella abortus* organisms. The greatest source of infection, however, is from direct contact with the infected animals. More serious forms of human brucellosis come from the swine type (*Brucella suis*) and the goat type (*Brucella melletensis*). Pasteurization of the milk kills the organisms.

Symptoms. The chief symptom of brucellosis is the expulsion of the fetus before time, although not all infected cows do abort. The abortion

[1] Rich. Cornell Veterinarian 21:15–24. 1931.
[2] Eckles. Minn. Agr. Expt. Sta. Bul. 258. 1932.

may occur during any stage of the gestation, but most abortions occur during the seventh and eighth months of gestation. Rich reports that more than 62 per cent of all abortions occur during these two months. Except in rare cases, cows once infected with brucellosis remain infected. The number of times cows abort varies. Rich found 78.6 per cent aborted but once, 19.7 per cent twice, and 8.3 per cent three or more times. Fitch and coworkers report one cow as having aborted six times and calved normally but once. Following abortion, discharges from the genital tract are common.

The organism gains entrance into the system through the mouth. Many different parts of the body may become infected, but the uterus is the most commonly infected during pregnancy. Big knees of cows may be caused by *Brucella abortus*, and the udder is frequently affected when the milk becomes contaminated with the organism.

Tests. Infected animals may be detected by a bacteriological examination of the aborted fetus milk, afterbirth, or vaginal discharges, or by the agglutination test of the blood. The latter is the more reliable, as many infected cows do not abort. Agglutination tests are reported as positive, negative, or suspicious.

The disease is spread directly or indirectly by discharges from the genital tract of infected animals or by milk from an infected udder. The discharge may be licked by the noninfected animals or may contaminate the feed or pasture grass later eaten. The fecal matter from animals having ingested the organisms, such as calves that have drunk infected milk, usually contains the organisms and may be a source of infection. Any place an infected animal has been—such as trucks, railroad cars, pastures, or barns—is likely to be contaminated with the disease germs, and is a possible source of infection for noninfected animals.

Treatment and control. There is no known cure for brucellosis. An animal once infected, even though she does not abort, carries and eliminates the organisms and becomes a dangerous spreader. This also is true for infected bulls. Although infection is not known to be transmitted directly to cows from the services of infected bulls, the organism from the infected bulls is spread in other ways. The commonly accepted plan is to eliminate all positive animals from the herd. A comprehensive plan for elimination of brucellosis from herds is available. By entering into an agreement with the United States Department of Agriculture, Bureau of Animal Industry, in co-operation with the various states, tests will be made periodically without cost to the owner; and a certificate of Accredited Brucellosis-free Herd will be issued when the conditions specified by the various states as requirements for such a certificate have been met. The owner must agree to dispose of all infected animals and to accept the appraisals made of such infected animals.

Many counties in various states are now designated as modified accredited areas as the result of area testing and slaughter of reactors. However, it seems to be more difficult to eliminate brucellosis from herds than it was to get rid of tuberculosis.

Several plans are suggested for consideration in attempts to eliminate brucellosis from the herds. These are as follows:

Plan 1 is known as the test and slaughter plan. All animals are tested and reactors are slaughtered. This plan requires the shortest time in elimination of the disease, is compulsory in areas under accreditation, and may work a hardship on individuals where a large proportion of the milk producers react. The test and slaughter may or may not be carried on together with calf vaccination.

Plan 2 provides for testing and vaccinating the calves, preferably at six to eight months of age, with strain 19 vaccine. The reactors are temporarily retained for production purposes or until such time that negative young stock will have grown into replacements for reactors.

Plan 3 involves calf vaccination without testing, continued until vaccinated animals have largely replaced the nonvaccinated ones.

Plan 4 provides for the vaccination of adults with strain 19. This plan should be used as a last resort and only in herds with an unusually high incidence of infection. Special permits for adult vaccination is required in many states. Animals vaccinated when mature retain positive reaction and cannot be told from those that are actively infected.

Tuberculosis. At one time tuberculosis was one of the most extensive diseases among cattle. Through the efforts of the Federal Government in co-operation with the several states and owners of cattle, the disease is now under control. In 1940 all counties in the United States had been designated as modified accredited areas with less than one-half of one per cent infection. Tuberculosis in cattle is of special concern to the public because human beings may contract the disease from infected cattle, particularly through the milk. Tuberculosis is due to the bacterium, *Tubercle bacillus*, which is a microscopic, rod-shaped organism.

Symptoms. Tuberculosis is, as a rule, a slow developing disease; therefore, very few infected animals will manifest any symptoms. In extreme stages the disease may cause death, but this seldom occurs. Although any part of the body may be affected, the lungs and lymph glands are the favorite places of attack. Tubercular lesions, however, are very common in the heart, udder, liver, and other internal organs. The disease gets its name from the character of the early lesions, or tubercles. In the early stages the tubercles are small cheeselike nodules that, when cut through, yield a gritty sensation. In later stages the whole infected organ may become a solid mass of yellowish-gray cheesy material.

How the disease spreads. Animals contract the disease from inhaling the germs or through the mouth. Infected animals may eliminate the germs in various ways. Infections of the respiratory tract will cause contamination of the air through respiration. Germs from the respiratory tract infection may also be eliminated in mucous discharge into the mangers or on grass and other places to be picked up by other animals. The infected mucous may be swallowed to contaminate the fecal matter. Any lesions along the alimentary tract will also cause the fecal matter to be contaminated. Infections of the mammary gland contaminate the milk, and the

disease spreads to the animals fed the milk. The tuberculosis organism is particularly resistant and will live for a long time in organic matter.

Control. The first requisite in control of the disease is the detection of the infected animals. Then all the infected animals must be eliminated, and the premises where they have been kept must be thoroughly cleansed and disinfected. The only way to detect infected animals is by applying the tuberculin test. There are three different tuberculin tests, all based upon the same principle—the infected animal's reaction to tuberculin. The three tests are subcutaneous, intradermal, and ophthalmic. In the subcutaneous test the tuberculin is injected below the skin, and the reaction is determined by characteristic temperature increases for infected individuals. The intradermal test consists of injecting tuberculin into the skin at the base of the tail. In infected animals a characteristic swelling will appear at the point of injection. The ophthalmic test consists of placing tuberculin in the eye; this test is used only when a check on the other two teats is desired. The intradermal test is the one commonly used because it is as accurate as any and is more rapid.

While the tuberculin test was discovered in 1882 by Koch, not until 1917 was any definite action taken to control tuberculosis among cattle in this country. At that time a voluntary agreement plan was offered to breeders of cattle by the federal government in co-operation with the states whereby, by testing and disposing of reactors until a herd free from tuberculosis was established, a certificate of accreditation was given. The plan proved so successful in eliminating the disease from individual herds that it was followed by the so-called Area Test Plan which has gradually been adopted by the states. Under the Area Test Plan all herds of cattle in a county which entered into an agreement were tested. When the per cent of infection in a county was reduced to one-half of one per cent or less, such a county was accredited. The same plan was later extended to entire states.

Johne's disease.[1] Johne's disease, named after Johne, the discoverer, is a highly infectious disease caused by an organism resembling the *Tubercle bacillus* and known as *Mycobacterium paratuberculosis*. The disease is also known as para tuberculosis. While it is not extensive, the disease is reported to be on the increase in this country. When the disease once gains entrance into a herd, it spreads rapidly.

Symptoms. As with tuberculosis, animals infected with Johne's disease are slow in developing definite symptoms. Johne's disease differs from tuberculosis in that all infected animals will ultimately develop the symptoms of the disease, and sooner or later all will die. The organism affects only the intestinal tract, producing a characteristic wrinkled condition of the intestinal mucous membrane. The temperature of diseased animals is normal. As the disease progresses, there is a loss of appetite, emaciation, and almost invariably diarrhea. The milk flow of infected animals drops rapidly, and the animal ultimately dies from "wasting away."

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[1] HASTINGS, BEACH, AND MANSFIELD. Wis. Agr. Expt. Sta. Res. Bul. 81. 1927.

The disease germs are eliminated in the feces of infected animals, through which the disease spreads to other members of the herd.

Control. The disease is detected from laboratory examination of the intestines of dead animals and by the use of Johnin injected intravenously or intradermally. When infection gains entrance into a herd, it may be eliminated only through the most rigorous measures involving frequent testing, elimination of positive reactors, and the disinfecting and cleaning of the premises where infected animals have been kept. There is the same government indemnity for Johne's disease reactors as for tuberculosis reactors.

Hemorrhagic Septicemia. Hemorrhagic Septicemia, is believed by some to be caused by the *Pasteurella bovisepticus.* It is highly infectious and is found in all parts of the country. While animals of all ages are susceptible, young stock are more often infected. The disease is also known as stockyards fever or shipping fever. Since many other diseases produce similar symptoms, proper diagnosis requires the services of a veterinarian.

Symptoms. As the name implies, the disease is a blood poison; and as is characteristic of blood poison, it runs a rapid course. Either death or recovery occurs in seven to ten days. The temperature increases to 105° or higher, and is accompanied by complete loss of appetite and great weakness. The lungs are frequently affected, as is evidenced by difficult breathing and coughing. This disease usually terminates in pneumonia and death. Post-mortem examination reveals characteristic pin-point hemorrhages on the heart and other internal organs.

Animals weakened because of poor nutrition or from traveling in railroad cars or trucks are most susceptible.

Treatment and control. Hemorrhagic Septicemia is treated in two ways. Bacterin is often administered to susceptible animals with the object of developing immunity and antiserum may be administered to the sick animals with the view of neutralizing the toxins. Cattle to be shipped or sold in public sales should be treated with the bacterin at least ten days before shipment or sale. Even this will not produce complete immunity. Antisera administration to sick animals has been only partially successful. Keeping the sick animal warm and comfortable and inducing it to drink water and eat are important factors in treatment.

In addition to immunization with bacterins of the susceptible members of the herd, complete isolation of affected individuals is essential to prevent the spread of the disease.

Trichomonad disease.[1] This disease is caused by a protozoan organism (the trichomonad) affecting the genital organs of both the male and female. It was first described in this country in 1932; since that time it has been reported in widely scattered areas, and apparently is on the increase.

Symptoms. Symptoms of trichomonad infection are not too well known as yet. Usually, shortly after infection, there is a swollen condition of the external genitalia of both the male and female; this is followed by a

[1] ANDREWS. Successful Farming. April, 1937.

discharge. These symptoms may persist or may subside. Only a laboratory examination will enable positive diagnosis. Infected females become either temporarily or permanently sterile. Pregnant females may abort; the expelled fetus may be normal, or it may be differentiated from other types of abortions by its disintegrated appearance. Frequently abortion does not take place. The dead fetus may be retained, causing an inflammation of the uterus or an abscess which continues to grow in size and give the external appearance of a normal pregnancy. When calving does not occur at the normal time, an inspection will reveal the uterus filled with a liquid. The disease is usually transmitted from an infected bull to the female at the time of service. The bull becomes infected from serving infected cows.

Treatment and control. Little is known as to how to control the disease. From the nature of its dissemination, it is apparent that infected bulls should not be used; and to prevent the bull from getting infected, he must not be permitted to serve infected cows. Artificial insemination of infected cows may be a solution to the problem.

Actinomycosis (lumpy jaw). Actinomycosis is an infectious disease caused by a fungus-like organism *Actinomyces bovis*. Similar lesions are produced by other organisms producing pus and, consequently, often diagnosed as actinomycosis. *Actinobacillus lignieres* produces lesions so like those of *Actinomyces bovis* that they can be told apart only by detailed laboratory examinations.

Symptoms. The typical case of actinomycosis is characterized by a lump on the lower jaw. The lump gradually grows until it may become the size of a man's head. When the swelling becomes large, it opens to discharge a pus which contains the organisms and which becomes a dangerous source for spread of the disease. The swelling is usually hard and attached to the jawbone, which may be greatly eroded from the effects of the disease. Other parts of the body may be attacked, including the soft tissues; an attack of the tongue known as wooden tongue is the most common. Positive diagnosis of actinomycosis may be made from an examination of the pus discharge. Passing a knife through the pus will reveal a gritty substance, which if examined under a hand lens will reveal ray structured bodies. The organisms gain entrance through the inside of the mouth from the food eaten.

Treatment. Doses of one and one-half drams of potassium iodide daily until the animal suffers from iodine poisoning is the most effective treatment. Iodine poisoning is manifested by a dry, scaly condition of the skin accompanied by weakness and loss of appetite. When these symptoms appear, the iodine treatment is discontinued for a few days. Removal of the swelling by surgery is seldom to be advised.

Milking cows will practically dry-off during the iodine treatment. As iodine is secreted in the milk, the milk produced during treatment is not fit for use.

Pink eye. Pink eye, or contagious sore eyes, is a very contagious disease affecting cattle of all ages. Unless preventive measures are taken immedi-

ately upon the appearance of the first case, the disease usually spreads rapidly throughout the entire herd.

Symptoms. Pink eye is an inflammation of the eye membranes that causes a reddening of the eye accompanied by a watery discharge and a swelling of the eyelids. The eyes become painful and extremely sensitive to strong light. Usually a slight fever accompanies the disease. In some cases permanent blindness may occur. Desire for feed decreases and milk production drops materially with infected milking cows.

The disease is spread by contact between infected animals and healthy ones, and by flies.

Treatment. The first essential is the removal of the infected animals from the healthy ones. The eyes should be washed with a saturated solution of boric acid to relieve irritation. A few drops of a 10 per cent argyrol solution may be placed in the eyes daily by means of a medicine dropper. Infected animals should be kept in a dark place protected from flies.

Foot rot. Foot rot, or foul-in-the-foot, as it is sometimes called, is an infection of the foot that causes great pain to the affected animal. The infection is due to pus-forming organisms that gain entrance through injured skin between the toes. Anything that causes irritation to the skin between the toes or around the hoof is a predisposing factor for the disease. Muddy yards or dirty pens not only by impaction of material between the hoofs cause irritation of the skin, but also constitute excellent places for harboring the pus-producing organisms. The disease is seldom found in cattle kept in dry, clean yards, barns, or pastures.

Symptoms. The first symptom is lameness. One foot or more may be infected. On examination the ankle will be found to be swollen and hot, and the integuments between the toes inflamed and decaying, giving off a foul odor. At first the decay is confined to the surface, but if it is not properly treated, it will form deep abscesses that will spread under the horny wall of the hoof. In extreme cases the hoof may slough off. Due to the pain animals lose their appetites and the milk flow is greatly reduced.

Treatment. Infected as well as healthy animals should be removed to clean, dry places. For the infected animals this is essential to facilitate healing, and for the healthy animals it is the best precaution against infection. If the infection is treated in the early stages, thoroughly cleansing the hoof with soap and water, scraping away the infected crusts, and applying a good disinfectant, such as one of the lysols, is all that is necessary. If the disease is advanced, the services of a veterinarian are required.

Cowpox. Cowpox is caused by a virus, *vacinnia*, which affects the skin of the udder, teats, and sometimes the inside of the thighs and belly. It affects horses and man, producing immunity to smallpox in the latter. The disease is spread by contact only. The disease causes annoyance in milking because of the attending soreness and is predisposing to mastitis because of bacteria entering the sores resulting from the broken pustules.

Symptoms. Cowpox at first produces a slight fever; this is followed by a reddening of the skin, increased warmth to the touch, and soreness. In about two days pealike nodules of a reddish color appear which grow in

size until by the seventh day they may be as large as one inch in diameter. The nodules then form blisters followed by scabs, which finally drop off to leave pits. The blisters contain a straw-colored fluid.

Treatment. Once cowpox has gained entrance into a herd it is difficult to prevent its spread. Were it not for the annoyance caused in milking and the predisposition to mastitis the disease would be of little significance, running its course in about three weeks. The problem in the milking cow is to allay pain during milking and guard against secondary infection, since there is no known treatment for the disease itself. Anything that will keep the sores soft so as to prevent breaking and bleeding at milking is indicated. For this purpose the application of 5 per cent sulfanilamide in lard or other similar vehicle has been found satisfactory. The sulfanilamide protects against secondary infection and the lard keeps the sores soft and less likely to bleed at milking.

Bloat.[1] Bloat, also known as hoven or tympany, is a condition in which the rumen becomes distended by accumulation of gases. Analysis of the gases by California [2] workers showed 67 per cent carbon dioxide, 26 per cent methane, 7 per cent nitrogen and hydrogen, 0.1 per cent hydrogen sulphide, and less than 1 per cent oxygen. While several feeds produce bloat, it is not due to special gas formation by these materials but rather to the failure of eructation of the gases produced at normal rates. Large quantities of gas are formed in the rumen from all forms of roughage at all times. Commencing about two hours after feeding of green alfalfa the amounts of gas produced increases from about five liters per hour to more than 20 liters per hour, three and one-half hours after feeding.

Four causative factors may be responsible for bloat.

1. Complete or partial obstruction of the esophagus may prevent the escape of the gas. Of these, choke from roots and tubers occurs with relative frequency. Tumors and growths in the esophagus sometimes causes chronic bloat.
2. Ruminal atony is regarded as a common cause of bloat, since vigorous contractions of the rumen are essential to push the gas forward to the cardiac orifice. Bloat can be produced by injection of histamine which causes atony of the rumen.
3. Feed stuffs that incorporate gas in small globules to produce a frothy condition of the rumen ingesta produces bloat. Presumably these feed stuffs contain a saponin-like material or similar substances that are formed in the ingesta.
4. The eructation mechanism becomes defective. This will account for the bloats that occur when there is active ruminal contractions. In this case it is presumed that the bloat-producing material contains substances that abolishes the eructation reflex.

Whatever the causes, the fact that all legumes may produce bloat under certain conditions prevents cattle owners from making optimum use of

[1] Cole, Huffman, Kleiber, Olson, and Schalk. Jour. Am. Sci. 4:183. 1945.
[2] Kleiber, Cole, and Meade. Jour. Dairy Sci. 26:929. 1943.

legumes for pastures because of the fear of losses from this cause. Other feed stuffs also may cause bloat. Heavy feedings of grain, particularly corn and very early cut legume hays, especially if frosted before cutting, may cause bloat as readily as pasturing immature legumes.

Symptoms. The symptoms of bloat are easily recognizable in its various stages. The first sign is a great distention of the upper left side of the abdomen, giving a lop-sided appearance to the animal. The animal becomes uneasy, and the respiration rate increases and becomes short and jerky. If relief is not given to the animal it will first stagger, then fall, and finally die from suffocation. The gas pressure in the rumen becomes great enough to prevent lung action.

Treatment. In cases where the gas pressure has not become too great, the gas may be released by merely walking the animal. In some cases, the gas pressure may be released through inducing belching by placing in the mouth a stick or rope that has been coated with some unsavory substance, such as pine tar or turpentine.

In some cases, the gas pressure is so great that it must be removed at once, and a puncture of the rumen becomes necessary. For this the trocar and cannula are employed, although in emergencies any knife may be used. If the animal has bloated sufficiently that a puncture is necessary, the anatomical landmarks have been obliterated and judgment must be exercised as to the point for puncture. The spot for the puncture should be in the center of the triangle formed by the last rib, the hipbone, and the transverse processes of the backbone. The trocar should be directed toward the middle of the abdomen by a sharp thrust. The cannula should be left in the wound until no more gas escapes, and then removed.

Recent experiments have shown that if sufficiently coarse prickly materials are present in the rumen before the bloat producing feed is consumed or taken with it, bloat may be prevented. Straws or coarse hays, if fed before animals are pastured on legumes, will make such pasturing safe. Mixtures of brome grass or wheat grass with alfalfa likewise will prevent bloat. The theory is that these materials are of a prickly nature and will stimulate rumen action and eructation.

Mastitis. The term mastitis is derived from the Greek word *mastos*, meaning breast, with the suffix *-itis* denoting inflammation. It therefore means inflammation of the mammary gland. Mastitis is the most serious disease problem confronting the dairymen. The actual loss from this disease is not known, varying from very small losses in some herds to virtually complete loss in other herds. The losses from attacks of mastitis include a decreased production from the destruction of mammary gland tissue and, in severe cases, from the systemic effect on the cow, loss of abnormal milk unfit for market, death of cows in certain types of attacks, the cost of treatment, and in additional labor and trouble involved in caring for infected animals.

Symptoms. No disease has a greater variation in symptomatology than does mastitis. Usually only one quarter is involved at a time but two or more quarters may show the symptoms. In some cases the attack may be so

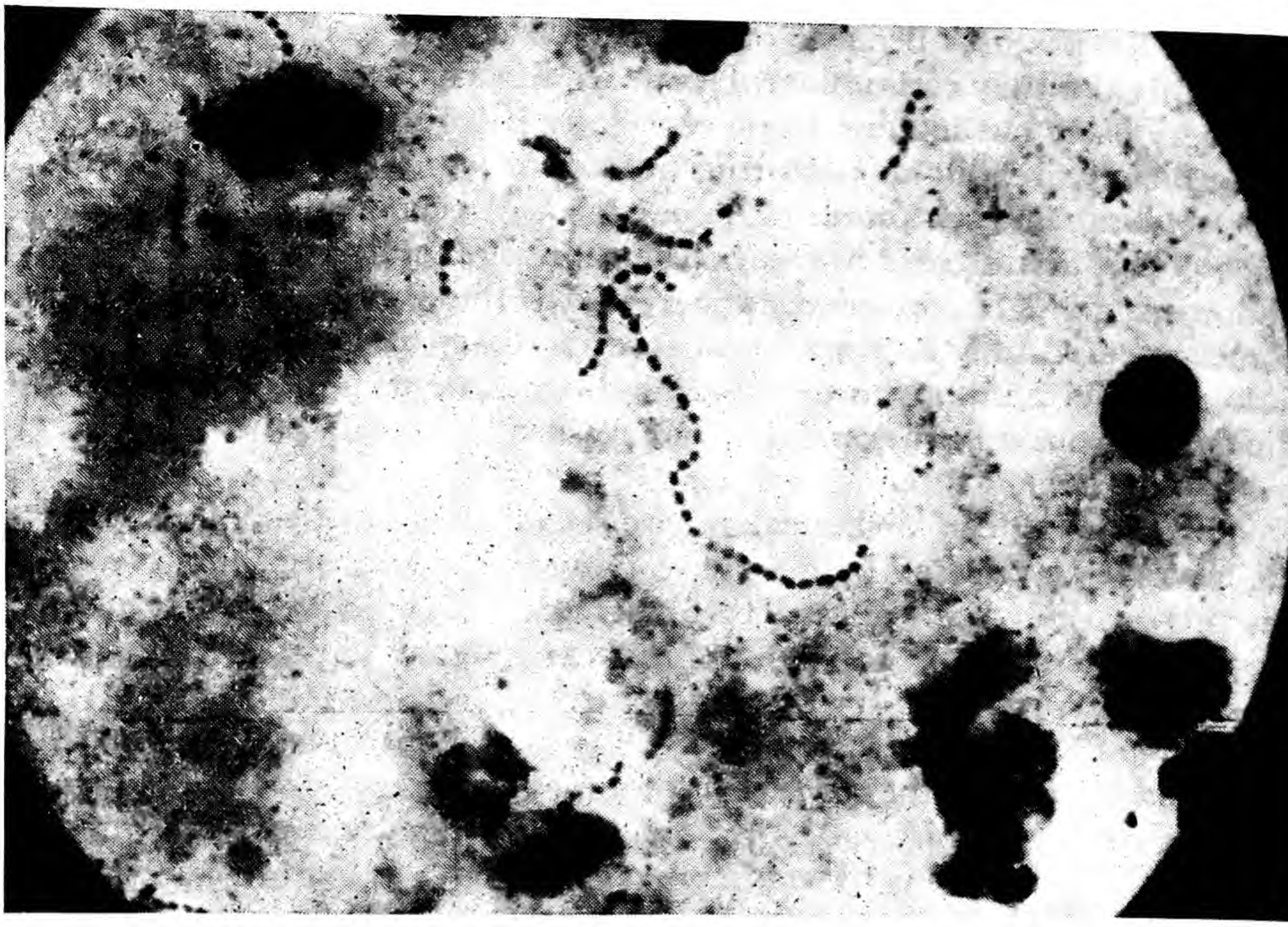

Fig. 94. Microscopic appearance of mastitis milk caused by streptococcus agalactiae. Bacteria appear as chains, and leucocytes as large dark bodies.

mild that it can be detected only by special laboratory tests. Sometimes the attacks become so severe that the animal is acutely ill, exhibiting a greatly elevated temperature and increased respiration, while refusing food and drink. Many of these animals, in spite of the best modern treatment, will not survive.

Some types of mastitis are characterized by a periodic flare-up in which the involved quarter or quarters may become swollen; the disease can then be detected by the clots in the milk. There may be spontaneous recovery from this phase, but recurrences—with each successive attack becoming more severe—are not unlikely. In other cases the first attack is so acute that milk production stops completely. In some cases such a quarter will recover to nearly normal following the next freshening. In other cases the quarter is permanently lost. Certain types of mastitis may cause the involved quarter to slough off. Staphlococci and coloform types of infections very often are responsible for this most acute type of mastitis.

Most generally, after an acute attack of mastitis, regardless of the response to treatment, there is permanent damage to the gland, in which scar tissue replaces normal tissue. This scar tissue may be detected by udder palpation. It is evident after mastitis has occurred.

Causes. While a few cases of mastitis may be physiological, that is, caused by systemic upsets without the presence of pathogens, the great majority of cases of mastitis reveal microorganisms associated with the

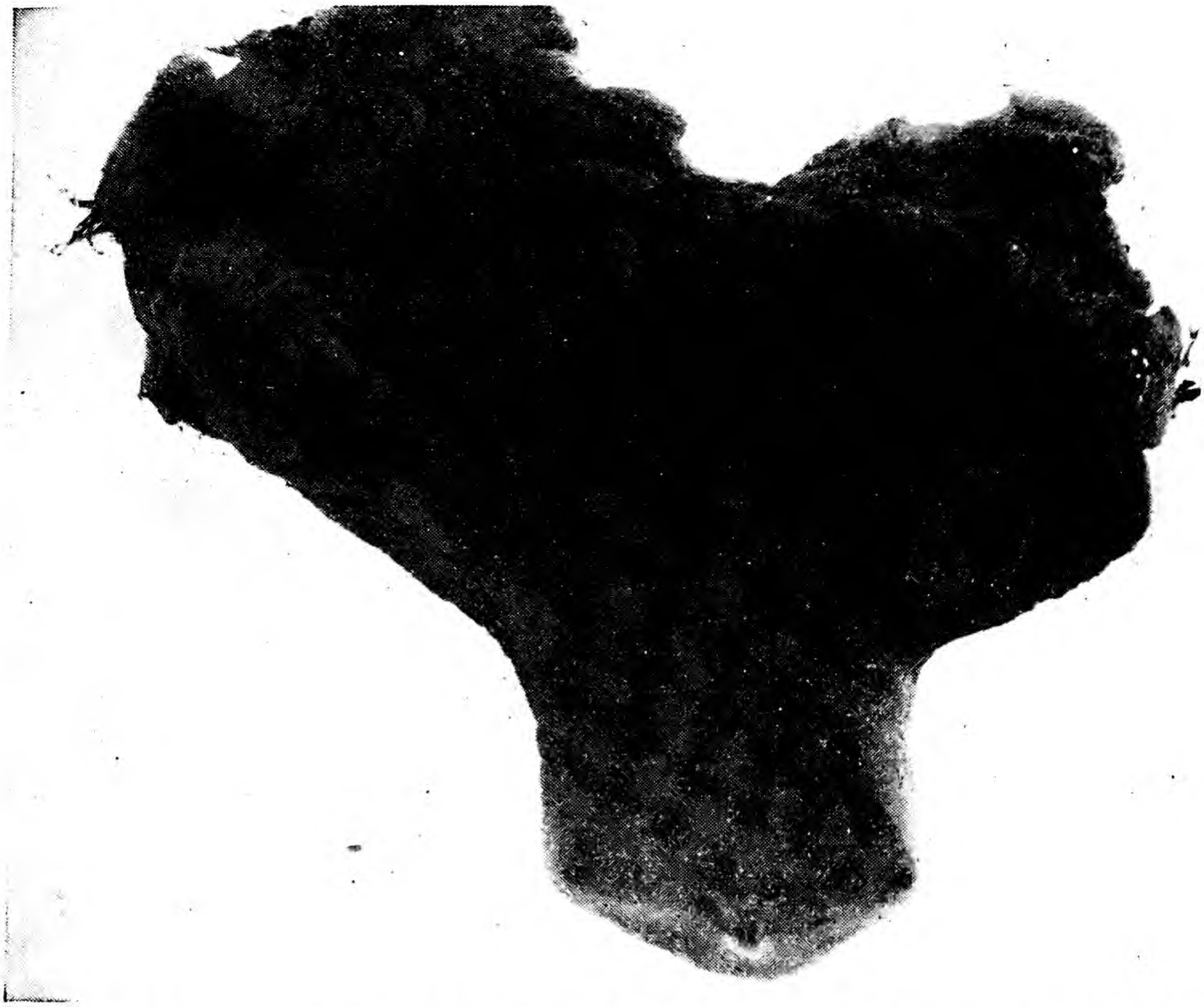

Fig. 95. Appearance of the inside of a normal teat. It is lined with a thin membrane free of growths with the blood vessels showing through.

disease. The most common organism associated with mastitis is known as *Streptococcus agalactiae*. However, many other organisms produce the disease, including those that are found at all times about the cow, the yards, and the pastures. Among the organisms causing the most severe attacks of mastitis are various staphlococci and coloform types. Mold and virus have also been reported as causative agents in mastitis.

The fact that microorganisms capable of producing mastitis are found about the cows at all times, indicates that other factors than the presence of the disease-producing organisms are necessary to produce mastitis. These may be classified as predisposing factors. Among them are all of those factors that tend to produce injury to the teat or udder. It has long been recognized by dairymen that whenever a teat or an udder is severly injured, such injury is usually followed by an acute case of mastitis. What has not been so generally recognized is that the relatively delicate lining on the inside of the teat and the udder may be injured in various ways that will facilitate the entrance of any organism that may be present and yet which cannot be detected by the most skilled operator. Breaks in the

Fig. 96. The inside of a teat with extensive fibrous growths resulting from leaving the milking machine on too long.

lining of the teat commonly occur from too rough milking either by hand or by mechanical milkers. Digging in with the finger tips and over vigorous stripping has been shown to cause breaks in the lining of the inside of the teat. Leaving the milking machine in operation too long also has the same effect. When milk does not flow out through the teat meatus, negative pressure enters the teat, with damaging results. The mechanical milker, when left in operation too long, will cause injury particularly to the accessory glands lining the upper inner walls of the teat. Acute mastitis has been found in these accessory glands when the rest of the quarter was still normal. Too short and too narrow stall platforms very often cause self-inflicted teat and udder injury. High door sills, particularly with a muddy condition outside, often cause great damage to the udder, resulting in a high incidence of mastitis. Brush and brambles, wire, and other debris left in yards, lanes, or pastures can and often does cause injuries to the teats and the udders that finally results in mastitis. It has also been shown that cold, wet, stall platforms are predisposing to mastitis. In addition, it has been shown that failure to evacuate all of the milk at a milking is predisposing to mastitic flare-ups. This is particularly true with cows that have chronic mastitis.

Diagnosis. In acute mastitis the inflamed quarter and abnormal milk is positive evidence of the presence of mastitis. However, since much of the

Fig. 97. A microscopic section through an accessory gland in the upper teat sinus wall that is attacked by mastitis. The alveoli are filled with materials containing large numbers of leucocytes. The gland may still be normal.

mastitis begins as a subacute form, it is highly desirable that it be then detected and that proper steps be taken in treatment and handling so as to prevent the possible spread of the disease. Much of this subacute mastitis can only be detected by special laboratory tests requiring special equipment and skills. There are, however, several tests that may be applied routinely by the dairymen that will help to detect most cases early and in that way make it possible to prevent, insofar as possible, the spread of the disease. The test that may be used by the dairymen are strip cup, brome-thymol-blue, Whiteside, and palpation.

Use of strip cup: Generally, mastitis produces clots of varying sizes which can be detected by the proper use of a strip cup. The first two streams from each quarter should be expressed into a strip cup and carefully observed for the presence of clots or abnormal consistencies—such as a watery appearance. In mechanical milking, use of the strip cup helps in opening up the meatus of the teat so that the rate of milk extraction will be at the maximum at the very beginning of action. The presence of clots should always be viewed with suspicion of mastitis. Small fine clots in the first stream or two, however, need not necessarily be indicative of mastitis. The cause of these small clots in the first stream or two, without mastitis being present, is not known, but cows have been observed to shed these periodically without ever having developed acute mastitis.

Brome-thymol-blue test: Reaction to the dye brome-thymol-blue is dependent upon the change it induces in the milk composition—which becomes more alkaline. Almost without exception in the case of mastitis the milk changes from its normal *p*H of 6.5 toward a more alkaline condition, due to the diffusion of sodium bicarbonate into the milk from the blood stream. There are, however, other conditions that will produce an alkaline reaction; thus great care must be exercised in condemning a cow because she reacts positively to the brome-thymol-blue test. In all cases colostrum will react positively, as will also the milk of late lactations. The brome-thymol-blue test can be conducted in two ways. In one, a half cc. of brome-thymol-blue solution is placed in a test tube and 10 cc. of milk added. If the color changes toward a blue-green, the reaction is positive. Another and simpler method is what is known as the blotter test. A drop of brome-thymol-blue solution is placed on a blotter for each quarter and a few drops of milk are expressed on this spot and watched for color changes. Sometimes in poorly ventilated barns the ammonia content of the air may be sufficiently high to cause color change.

Whiteside test: The Whiteside test is dependent also upon abnormal milk to produce reaction. It is roughly correlated with the leucocyte content of the milk. Like the brome-thymol-blue test it is not infallible. In some cases of mastitis it will not react positively and in other cases it will give false positives. It is, however, simply conducted, is inexpensive, and of value in detecting early mastitis when good judgment is used in the interpretation of the results. To conduct this test, place on a glass plate a solution of 4 per cent of sodium hydroxide and employ some simple instrument for stirring—such as a toothpick. Five drops of milk are placed upon a glass plate, one drop of the sodium hydroxide solution is added by means of a medicine dropper, and the mixture is stirred for about 20 seconds. Normal milk will give a homogeneous mixture following stirring. Clumps of varying sizes will result with decreasing leucocyte content of the milk. The microphotographs in Figure 98 present the different reactions that are obtainable by the proper use of the Whiteside test.

Palpation: One of the most useful skills of the milker is that of being able to detect slight changes in the feel of the udder. Any time that the udder or a quarter thereof has become slightly congested or nodules can be detected therein, mastitis infection should be suspected. Few people, however, are able to develop the skill of palpation sufficiently to be able to detect abnormalities early enough.

The tests for mastitis that can be carried on at the farm are not, as has been pointed out, infallible and do not give any indication as to the type of organism that may be involved. More accurate laboratory tests together with skilled bacteriological examinations are necessary for a complete diagnosis of mastitis. To carry on the bacteriological examination it is of importance that the samples are taken asceptically. This will require that the samples be taken by one who has had actual training in doing the job properly. The following are some of the more commonly used laboratory tests for the diagnosis of mastitis.

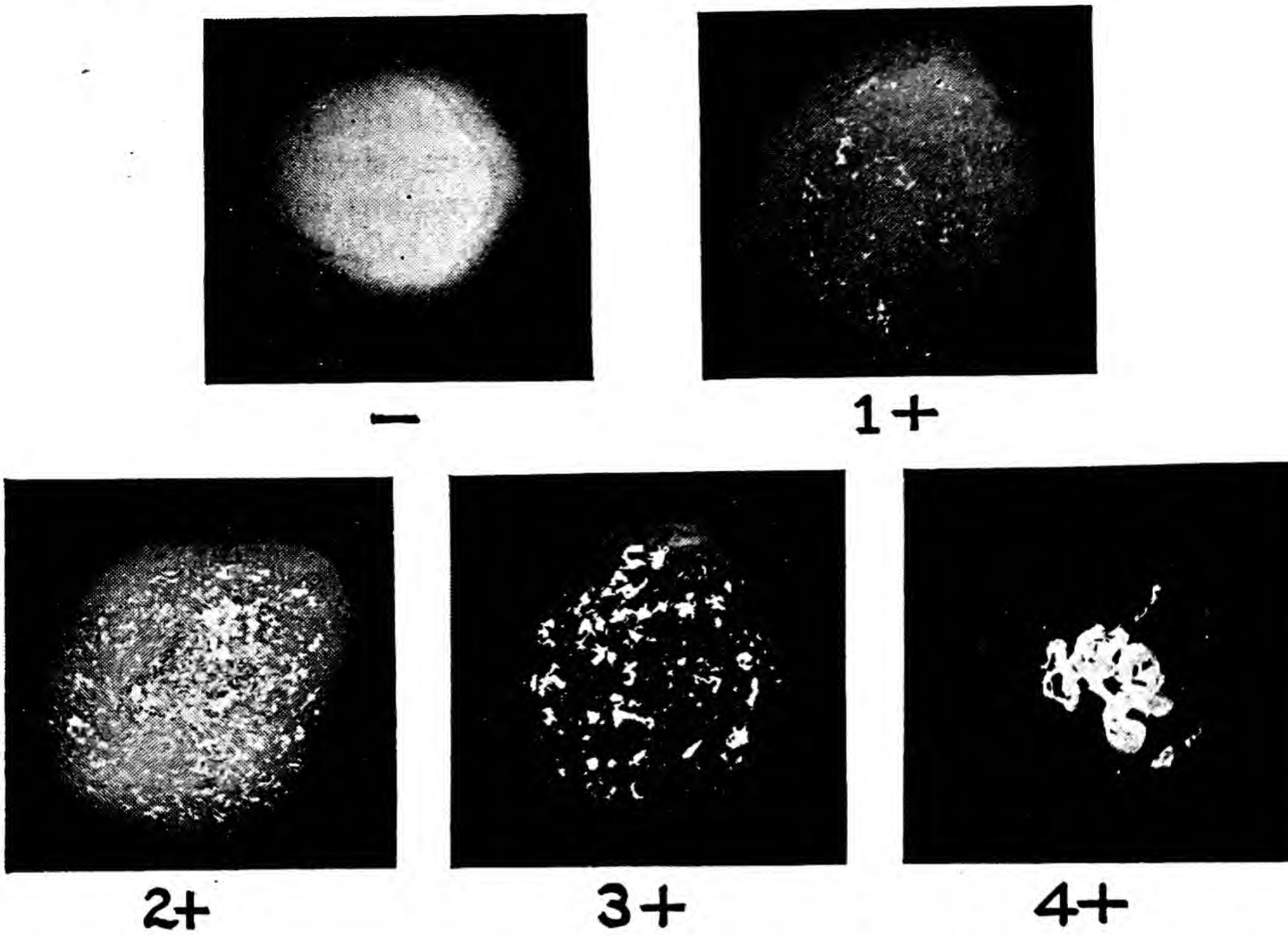

Fig. 98. Different reactions to the Whiteside test. In addition to the above five classes a class can also be established which has but very few small clots.

The Hotis test: The Hotis test consists of incubating a sample of milk with a dye, bromcresol purple, for 20 hours at 37° C. The bromcresol purple is made up at the rate of ½ gm. of the dye to 100 cc. of distilled water. Half a cc. of this solution is placed in a tube, preferably with a screw cap, of a capacity of 12 to 15 cc. The tube and its contents are sterilized in an autoclave. The udder of the cow from which the sample is to be taken must be carefully cleaned on the teat and particularly the end of the meatus sterilized with a 70 per cent alcohol solution, a solution of 200 parts per million of chlorine, or a strong solution of one of the good wetting agents. Approximately 9½ cc. of milk is then drawn into the tube, after which it is placed in the incubator for 20 to 24 hours. Reading the reaction of the milk can then be made immediately, since bromcresol purple is an indicator dye. Its turning blue is an indication that the milk is on the alkaline side. The sample taken in the Hotis tube may be used for further bacteriological analysis; a smear may be made from it for microscopic examination and the reaction exhibited after its incubation will be indicative, within limits of the type of organism causing the mastitis. If the sides of the tubes contain yellow flacks, the presence of streptococcus agalactie is indicated. Many authorities claim this to be absolutely specific for the identification of this organism. The yellow spots in the Hotis tube are caused by the streptococcus agalactie which, in

forming lactic acid at that point, changes the dye to yellow. Other organisms will form lactic acid and cause a uniform yellowing.

The positive reaction to the Hotis test does not necessarily mean that active mastitis has been discovered. Many cows can shed the organism for long periods of time without showing any other signs of mastitis. Streptococcus agalactia, however, is spread only from infected to noninfected cows and to find on animal shedding the organism indicates that it is a potential spreader of the disease.

Direct microscopic method: One of the most useful of all mastitis tests is that of the direct microscopic examination. After the asceptically drawn milk sample is thoroughly mixed, .01 cc. is spread over an area of 1 sq. cm. on a microscopic slide by the use of a standard pipet or wire loop made for this purpose. The slide is then dried and immersed in Newman's stain for two minutes. The slide is again permitted to dry and excess stain is washed out in distilled water. After drying, the field is examined by the use of the oil immersion lens and a microscope that has been calibrated so that the number of leucocytes or bacteria, as the case may be, per cubic cm. of milk can be estimated.

By this method an accurate estimate of the leucocyte content can be made and a general idea formed as to the type of bacteria that are responsible for the disease. The smear may be made from a Hotis sample, after it has been incubated for 20 to 24 hours; if leucocyte numbers are large and bacteria usually associated with mastitis are found, a positive diagnosis of the disease can be made. In the case of mastitis the leucocyte content of the milk is greatly increased. Making a diagnosis, however, or leucocyte count alone is not reliable. Usually when milk contains over 500,000 leucocytes per cc. it is abnormal and indicative of some type of infection. However, in late lactation and in several other cases, the leucocyte count may exceed a million without indicating the presence of mastitis.

Chloride test: Normal milk contains only about one-seventh the amount of chloride that is found in blood. In the case of mastitis the chloride content of the milk increases toward the leve of that found in the blood. Determination of the amount of chloride in the milk is, therefore, one of the tests that is valuable in the diagnosis of mastitis. To determine this chloride content two solutions are made up, one of silver nitrate c.p. 1.3415 gm. to 1000 cc. distilled water, the second of potassium chromate c.p. 10 gms. and distilled water, 100 cc. To one cc. of milk, 5 cc. of the silver nitrate solution is added, plus two drops of the potassium chromate solution which are mixed by inverting the tube. If the milk turns yellow, it is an indication that more than 14 per cent of chloride is present in the milk, which is considered abnormal, and if a brownish red color is present, it is less than that amount. While nearly all mastitis contains chlorides in excess of 14 per cent, that level of chloride may be present in milk that is not from mastitic quarters. Therefore, other factors must then be taken into consideration in conjunction with the chloride test before a positive diagnosis can be made.

Catalase test: The enzyme *catalase* is found in most living cells. The leucocytes in milk contain this enzyme and, therefore, the quantitative determination of the amount of this enzyme is another way of getting the approximate number of leucocytes. For the determination of catalase a 1 per cent of hydrogen peroxide solution is used. Five cc. of the hydrogen peroxide solution is placed in the test tube of 20 cc. capacity. This tube is fitted with a stopper having an S-bent glass tubing in it. Fifteen cc. of milk, when it is freshly drawn, is added to the tube and inverted. Then it is placed in an incubator at 37° C. for three hours. The enzyme catalase will split hydrogen peroxide into water and oxygen. The liberated oxygen will displace the milk in the tube, forcing it out through the S-bent tube; thus the amount of hydrogen peroxide used up in the reaction can be ascertained.

Normal milk always has some cellular content and will produce, under the specifications just given, from 0.25 to 1.5 cc. of oxygen. Milk producing over 1½ cc. is considered abnormal. Again, as with all other tests so far discussed, a positive reaction must be taken in conjunction with the other factors before positive diagnosis of mastitis can be made. All other factors that contribute to the increase of leucocyte content will increase the amount of gas liberated.

*p*H test: Normal milk has a *p*H of 6.4 to 6.6. As the mammary gland becomes affected with mastitis, sodium bicarbonate passes from the blood into the milk to raise the *p*H value. With the modern *p*H meter the values for acidity can be rapidly determined. In order to accurately represent the *p*H of the milk the test must be done before any bacterial action has time to take place. In other words, it must be conducted on fresh milk. The *p*H values exceeding 6.6, although not positive in diagnostic value, should be looked upon with the suspicion that infection may be present.

Cultural bacteria methods: For positive diagnosis of the causative organism of mastitis, laborious bacterial cultural method must be carried on. These procedures require skilled technicians with adequate laboratory facilities and will prove too expensive to be used routinely as a control measure in the average dairy herd.

Treatment. A relatively large number of treatments have been developed for mastitis. Some years ago mastitis was only treated by the systemic administration of various drugs to the cow. While systemic treatment is not contraindicated in some types of mastitis, where it is necessary to eliminate systemic infection this approach to the treatment of the disease has been virtually discontinued. The presently accepted methods for the treatment of mastitis require intramammary administration of the therapeutic agent plus whatever supporting measures that may be needed for systemic treatment. Only very small amounts of any drug that is administered orally or parenterally will get through the mammary membrane and into the milk. On the other hand, the drugs that are now used for intramammary treatment will quickly diffuse through the entire quarter, provided the ducts are not shut off by disease processes. And a much higher concentration can be built up and maintained in the

udder by that method than can ever be hoped for should drugs be discovered which will diffuse readily into the milk.

While a large number of drugs are used for intramammary treatment, only a few of those more commonly used will be discussed here. Therapeutic agents for mastitis fall into two general groups, the chemical and the antibiotics.

Drug treatment, while it is valuable in mastitis control, thus far cannot be listed as a solution of the mastitis problem. Some cases of mastitis respond very well to treatment—others only moderately so and still others are not benefited by any of the treatments now available. In addition to this not too hopeful situation, once there has been an acute attack of mastitis irrevocable damage to the mammary gland has occurred. Scar tissue will have been formed that will replace normal secretory tissue and the milk subsequent to treatment will not return to the normal, pre-disease condition. There is also evidence that once a quarter has been infected with mastitis, even though good results may be obtained from treatment, its resistance will have been impaired and the organ become more susceptible to reinfection—often from a different organism than the original offender. There are, however, sufficient benefits to be gained, on an average, to make treatment of all cases of mastitis by a suitable agent worthwhile. The selection of the therapeutic agent will depend upon the type of mastitis. For instance, there would be no use in administering penicillin to a case of coliform mastitis, since this drug is completely destroyed by this organism. One other point needs to be stressed in conjunction with the consideration of the treatment of mastitis and that is that to be most effective the treatment must be administered at the first sign of the disease, and finally, whatever the treatment may be, it is important that asceptic conditions prevail in its administration.

Penicillin: The drug most commonly used today in the treatment of mastitis is penicillin. This drug is most effective on streptococcus agalactie, other streptococci, and some of the staphylococci. It is ineffective against the coliform group and many others. In spite of its limitations, the drug is administered by most dairymen in the case of mastitis regardless of what the causative agent may be. Penicillin is available in different forms. One of the most common is that of a dry powder of either sodium or calcium salts that is dissolved in distilled water before being infused into the mammary gland. Sterile distilled water is the fluid of choice for solutions of this drug. Other preparations contain penicillin suspended in oil and in still other cases penicillin is put up in materials to form bougies that may be inserted directly through the teat meatus into the teat canal.

Penicillin has no irritating effect upon the glands. As much as 500,000 units have been infused in distilled water into a normal quarter without evidence of any irritating effects. Therefore, the administration of this drug even though it may not be effective upon the particular organism involved has no harmful effect. In all probability too little of this drug is infused to do the optimum good and too often it is left in for too short a time. Studies have shown that penicillin, once infused into the udder,

diffuses out very slowly. It is therefore recommended that the cow not be milked for 24 hours after a treatment, provided that enough of the drug is infused in the first place. The optimum dosage is not as yet well established but probably never less than 50,000 units should be infused and 100,000 units may be better.

Streptomycin: Very little is yet known about the place that this drug will take in the treatment of mastitis. To date it has been too scarce and too costly to have entered into the treatment of mastitis to any extent. Theoretically, streptomycin should be very effective on organisms against which penicillin is ineffective. In recently conducted experiments it is shown that streptomycin behaves like penicillin in that it is not irritating to the mammary gland and that it diffuses out very slowly. Consequently, the mode of administration, provided that the drug should prove effective against mastitis, should be much the same as that of penicillin.

Tyrothricin: Tyrothricin is also an antibiotic, being isolated from a soil bacteria and containing two substances, tyrocidin and gramicidin. This drug is very effective against a large number of organisms. However, the drug is very irritating when introduced into the mammary gland and causes severe inflammation when introduced into the normal quarter. The drug is put up in various forms and under varying trade names. It is recommended that from 80 to 120 mg. of the drug be administered per quarter, depending upon the size. It is also necessary that the treatment be repeated two or three times, with a day intervening between each treatment.

Silver oxide: One of the most effective germicidal agents is silver oxide. For mastitis treatment it is usually put up as a 5 per cent silver oxide in mineral oil. This drug is one of the most irritating of drugs that has been used for the treatment of mastitis. In the recommended dose, when introduced into a normal quarter, it produces severe inflammation—the mammary gland normal function being permanently impaired. The drug may find use, however, in the treatment in cases which persist in shedding mastitis organisms after other treatments have been used. It is recommended that when this drug is used, it be preferably used on the dry udder. The normal dose is 10 cc. of a 5 per cent solution of silver oxide in oil injected per quarter and left in the dry quarter. When used on lactating quarters, the same dose is used on three successive days with milk-outs in between.

Sulphanilamide: Sulphanilamide, the first of the so-called sulpha compounds, has been used extensively in the treatment of mastitis. It may be put up in different forms but that most commonly used is the 35 to 40 per cent suspension of the drug in mineral oil. From 50 to 100 cc. of such a suspension should be infused into the involved quarter, depending upon the size. The larger quarters need larger quantities of the drug than smaller quarters. The usual recommendation is to administer treatment on three consecutive days with milk-outs in between. Sulphanilamide, like the other sulpha compounds, is moderately irritating to the mammary gland. When infused into the normal healthy quarter, the quantity of milk will

be reduced following the infusion of several days and the milk will assume the characteristics of fairly acute attacks of mastitis. Complete recovery, however, is the rule within four or five days.

Sulphathiazole, sulphamerazine, and other sulpha drugs are used in much the same manner as sulphanilamide, either individually or in combination. Iodine in one part to 1,250 parts of oil has also been tried as well as many other dyes and chemicals. None of these seem to present the properties that are not possessed by drugs that have been discussed.

Prevention of mastitis. The only satisfactory solution of the mastitis problem comes in its prevention. To prevent mastitis involves careful detailed attention to the important management factors and the carrying on of approved sanitary procedures. The most important single factor in mastitis control is that of preventing injuries to the udder and teats of which proper milking ranks high in importance. Milking should be carried on according to the procedures described in Chapter 35.

Proper housing ranks high in importance in a control program for mastitis. Stalls should be wide enough so that the leg action of the cow in getting up is free. In narrow stalls the leg strikes the partition, and throws her out of balance when she attempts to rise, often resulting in injury to the teat and the udder, followed by acute mastitis. The stall platform should be long enough so that the udder does not extend over the end of the platform when the cow lies down. Studies at the University of Minnesota show that the incidence of udder and teat injury and subsequent mastitis involvements was many times as high in cows that stood next to supporting posts which were placed in line with the stall partition and the gutter. These posts, particularly when stalls are narrow, interfere more than the stall partition with the rising action of the cows. As has been previously stated, door sills and approaches to the barn can be serious factors in the udder and teat injuries that are so predisposing to mastitis.

Increasing evidence is being accumulated showing that deep, dry bedding is an important factor in preventing mastitis. Loose housing, when kept dry, has an effect of diminishing the incidence of mastitis.

After making provision for minimizing the possibility of injury and making all possible provisions for maintaining a healthy udder of high resistance, the important factor of preventing the spread of infection that is present must be considered. While many cases of mastitis are caused by organisms that are always present, the most prevalent type of mastitis is that caused by an organism which is spread from infected to healthy cows. It is therefore, necessary to ascertain the infected animals by proper tests and to milk them last, taking extra precaution that the milk from these cows will not come in contact with healthy ones. Whenever a cow shows any sign of mastitis, she should be milked at the end of the string that is otherwise normal. In addition to that it may be well to use disinfectants and washes of the udder before milking, the dipping of the teat cup in a disinfectant, or in the case of hand milking and hand stripping, the washing of the hands in a disinfectant between each cow. Two hundred parts per million of chlorine, while not too effective as a germicide on the udder

and teat, may be of some value in this connection. Some of the new wetting agents of the quarternary ammonium compound may be more effective for this purpose.

In spite of the shortcomings that have previously been stated about the various treatments, it is advisable that all animals who react to the mastitis test should be treated.

Lastly, cows with chronic mastitis that do not respond to treatment sooner or later become unprofitable. When this fact is considered in connection with the undesirability of having such cows in the herd and the possibility that they may be sources of infection that can spread to the healthy ones, it becomes apparent that they should be disposed of more often than is the case. Dairymen who have practiced these good management suggestions find a much lesser incidence of mastitis than do those that ignore sound management. Accidents will occur in any herd no matter how well they may be managed; and consequently, one cannot expect to have complete elimination of mastitis. The problem for the herd managers is to so handle and manage the herd that the incidence of this disease is reduced to the absolute minimum. The author has investigated herds where good management practices have been carried on for many years and was convinced that streptococcus agalactie infection has been present and yet never gave any appreciable trouble. The importance of good management in the control of mastitis can hardly be stressed enough.

Chapter 39

DAIRY BARNS

EFFICIENT MANAGEMENT OF A DAIRY HERD REQUIRES ADEQUATE EQUIPment properly arranged. Careful planning in the location, construction arrangement, and equipment of the various building units essential to dairy farming will prove to be labor saving and a real investment. Lack of planning in building and equipment arrangement may increase the labor requirement and prove to be a poor investment. While adequate buildings and equipment are necessary for efficient management, too elaborate and costly buildings and equipment may be too big an overhead for the dairy to carry.

In addition to being planned so that they will best serve the needs of the dairy and reduce the labor requirements, the dairy buildings should be made attractive. Neat and clean premises with an attractive set of buildings are valuable assets in marketing milk and cattle, as well as the source of a great deal of pride and satisfaction to the owner.

The list of buildings that are, as a rule, needed for the dairy enterprise is headed by the barn, with the milk house the next in importance. In addition, the yards about the buildings, silos, and calf and bull barns are important considerations. It is not the purpose of this discussion to go into the details of construction of the various farm buildings, but rather to take into account the fundamental considerations in locating, arranging, and equipping the dairy buildings.

Requirements of a satisfactory barn. While there are a multitude of details that must be considered in planning a satisfactory barn, they can be grouped into five main divisions:

1. Comfort and health of the cow
2. Convenience and labor saving
3. Sanitation
4. Durability of structure
5. Attractiveness

The first purpose of the dairy barn is to furnish the dairy cattle with protection against the elements. Exposure of cows to either severe cold or extreme heat causes great economic losses in lowered milk yields, disease, and sometimes death. Whenever a cow becomes uncomfortable, lowered milk production results. In addition to making a cow uncomfortable, exposure to cold requires an increased amount of feed for the generation of heat. Exposure to cold, moisture, and drafts is one of the predisposing factors for colds, pneumonia, and mastitis, all of which result in losses.

Since most of the work about the dairy is done in the barn, the arrangements should be made with a view to labor saving. The management of

the stalls and pens, feed and cleaning alleys, and feed sources should be such that a minimum amount of labor is required to feed the cattle and clean the barn. Labor saving materials and devices that are not too costly should be installed. A warm, comfortable, light, and clean barn is conducive to getting the most out of labor.

Milk, from which all dairy products come, is usually drawn in the barn. This product is the most valuable of foods, but it is susceptible to bacterial and sediment contamination which detracts from its wholesomeness, and unless the barn is kept clean, this contamination will probably result. Since cows kept in a light, clean, and dry barn are cleaner than those kept in a dirty barn, less dirt and bacteria will come into the milk. A clean, light, and neat environment is also conducive to cleaner methods of milking. In facilitating the cleaning of the barn, the materials and construction of the barn play an important part. For the production of certified and grade A milks, the minimum requirements for the interior construction are specified. Smooth surfaces on walls, ceilings, and floors that can be washed are to be preferred and are required for high-grade milk production. Adequate ventilation to purify the air and remove moisture is an essential. Moisture accumulating on the ceiling and walls is conducive to mold and bacterial growth, as well as the accumulation of dirt. Dripping of moisture from the ceiling soils the animals and makes for greater contamination of the milk.

Durability of the material used in construction is obviously an important consideration. Not only will a barn constructed of durable material last longer than one in which less durable material is used, but it will be easier to maintain in a sanitary condition. Broken decaying wooden parts or pitted and cracked concrete floors are not only unsightly but are conducive to the accumulation of dirt and microorganisms.

Location of the barn. A number of factors must be taken into consideration in locating a barn. One of the most essential considerations is that of adequate drainage. The barn should be located where there is good drainage away from it, and where adequate yard space, also well drained, is available. The next consideration is that it should be sufficiently distant from the house to minimize the odors that are always present. One hundred fifty to two hundred feet is considered the proper distance. As the barn is a place to which feed and from which manure and milk are hauled, it is desirable that it be located near a road. It is also desirable that the barn and adjacent yards be protected with trees, if it is at all possible.

The question as to which direction the long axis of a long barn should run is still subject to debate. Most people seem to favor a north and south direction of the long axis, claiming more effective exposure to the sun's rays as the reason. When the barn runs north and south, rays from the rising and setting sun can sweep the entire inside of the barn during the course of the day. Proponents of the east and west direction of the long axis of the barn claim greater effect of the direct rays of the midday sun. They also point to the desirability of the greater protection of the east and west direction of the barn from the north winds to paddocks located on

the south side. Another important consideration is the convenience of the location to pastures.

Types of barns. There are several bases upon which barns may be classified, such as the type of material with which it is constructed, the use to which it is put (milking barn, mixed horses and cattle, etc.), and the general plan of the barn. The latter is the most common way of classifying the barn. On this basis of classification there are six distinct groups, each group having several modifications:

1. The one-story barn
2. The two-story barn (with hayloft)
3. Basement barns
4. The lean-to barn
5. The round barn
6. The so-called resting shed

The one-story barn. The one-story barn is the most specialized of the types of barns housing only the cattle. Feed storage is arranged for in buildings outside the barn or in a building connected with the barn. Most one-story barns are wings of a two-story structure furnishing storage for feed. The chief advantages of the one-story barn, as compared to the two-story barn, are that it is free from the dust and dirt that filters down from the storage space above a two-story barn, that it permits lighting from the ceiling, and that better ventilation can be obtained.

The chief disadvantages of the one-story barn are that it is more expensive than a two-story barn when the additional cost of feed storage buildings is considered; that in colder climates it is likely to become too cold because it does not have the benefit of the insulating effect of stored hay; and that increased labor is required for carting the feed from the storage barn to the cattle.

The two-story barn. Except in the South, the two-story barn for dairy cattle is the most popular type. Cattle are kept in the first story, and hay and feed are kept in the second story. The two-story barn is more economical than the one-story barn from the standpoint of the cost of construction per unit of cattle and storage needed, and also in the saving in labor requirements for carting feed. This type of barn is also warmer because of the insulating effect of the stored hay and feed in the second story. Where the ceilings are tight, these barns are no more unsanitary from the dirt falling through the ceilings than are the single story barns. In cold climates, with the same ventilation they are perhaps more sanitary, as there is less condensation of moisture on the ceiling and therefore less dripping.

There are several modifications in which parts may be one story. Typically the two-story barn is rectangular, but it may be L-shaped, T-shaped, or U-shaped, in which all may be two stories in height or part may be but one-story structures.

The basement barn. A basement barn is a two- and occasionally a three-story structure in which one or more sides of the first story are below the surface of the ground. This type of barn is popular in hilly regions, the barn being located on the side of the hill. The floor of the second story is usually on the ground level and can be driven into—one of the advan-

tages of this type of barn. Another advantage is that of warmth in the winter and coolness in the summer due to the protection of the side or sides under the ground surface level. The chief objection to the basement barn is made on the grounds of sanitation. As one or more walls are below the surface of the ground, basements cannot be adequately lighted, nor can the interior be properly exposed to sunlight, and, as a result, they are generally damp and musty.

The lean-to barn. As the name implies, the lean-to is a one-story structure built against the side of a two-story barn. This type has the advantages of low cost and of warmth, particularly when constructed on the south side of a two-story structure. Usually lean-to barns are inadequately lighted, particularly if they are more than 20 feet in width, and they are unusually warm in the summer if they are on a southern exposure. The light, however, may be adequate and excellent if the barn is equipped with skylights.

The round barn. Except in a few communities the round barn has not met with popular favor in spite of the lower cost for materials. Frazer states that rectangular barns require from 34 to 58 per cent more material than round barns for the same floor area and grade of material. The round barn is invariably a two-story structure with the haymow in the second story, and sometimes in the center. More often the center is occupied by a silo. The cattle are arranged in a single row around the barn, usually facing inward. By this arrangement feed is conveniently located and labor is saved in feeding.

There are several objections to round barns that account for their lack of popularity. No satisfactory way of easy access to the silo or haymow has been found without loss of space. The lighting of barns of large diameters is a problem. The north side is not exposed to the sun's rays, and the center of the barn is too distant from the windows to be adequately lighted.

Type of materials used in barn construction. The type of material to be used in dairy barn construction is that which is the most durable and attractive, and will give the most comfort to the animals consistent with cost. The materials that conform to these requirements vary in different regions, depending upon the climate and the relative costs of the different materials. Brick, tile, stone, and concrete are the most durable and when properly constructed with proper air spaces and wall thickness, will adequately protect against both the cold and the heat. In most places, however, the cost of these materials and additional labor costs in construction make them prohibitive. Wood is, therefore, the most commonly used building material for barns. With the proper care wood may be made durable. Concrete, stone, or brick foundations should be built sufficiently high to bring the wood out of the more moist lower portions.

Wood is an excellent insulating material, and tightly matched inch boards on both sides of the studs furnish adequate protection against cold in the most rigorous climates. Paint and proper ventilation are essential to the preservation of wood in barns.

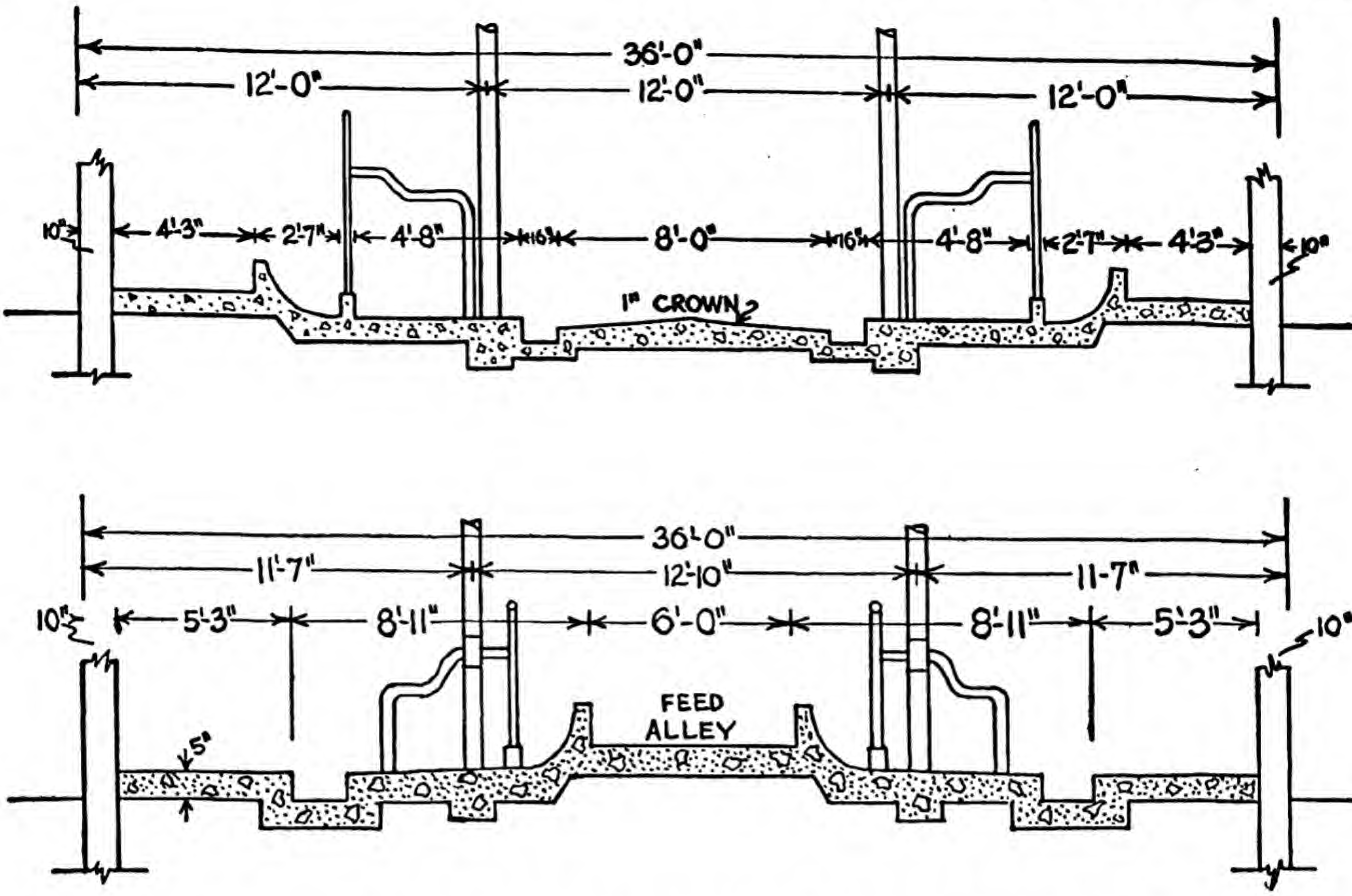

Fig. 99. Cross sections of barns where cows face out (*above*) and in (*below*), showing the proper allocation of space to stalls, alleys, mangers, and gutters.

In warmer climates a single thickness of matched one-inch boards is adequate and there is no need for the more expensive brick, stone, concrete, or tile construction.

Planning the interior of a barn. Careful planning of the interior arrangement is essential for economic utilization of the space and convenience in doing work. Before plans are made for the interior, a decision must be made as to the number of head the barn is to house, and the proportion of mature milking cows, yearlings, and calves that are to be kept. From this, the dimensions of the barn and apportionment of stalls, box stalls, and calf pens can be made. In arranging the interior the question arises as to whether cows are to face in or out, and the size and location of alleyways and cross alleyways are also to be decided. Other problems involve the choice and size of the stalls, and the kind of floors to be used for the stalls and alleyways.

Which way to face cows. Whether to face cows inward or outward in barns is a question that is still controversial. There are advantages for each system, and the choice is a personal matter. The advantages for facing out are:

1. The central passageway may be made wide enough that a manure spreader may be driven through.
2. Milking is made more convenient.
3. The herd shows off to better advantage, as cows are viewed best from the rear, and all can be seen from the one passageway.

4. The walls of the barn are more easily kept clean.
5. Cows may be let in and out of one door.

The advantages for facing in are:

1. Easier feeding, as all is done from one central alleyway.
2. More light for milking.

Dimensions. Of the three dimesnions, height and width permit but slight variation, while length varies with the desired capacity of the barn. In cold climates height may vary from 8 to 9 feet from the floor, while in warmer climates a greater height is desired. A height of 8 to 9 feet will give from 500 to 600 cubic feet for each animal, which is about the limit of space that can be properly warmed from the heat generated by the animal. In the South more space is desirable to prevent overheating by the animal during the long warm season.

Experience has shown that for rectangular barns a width of 34 feet, when cows face out, and 36 feet when they face in, is the minimum for satisfactory spacing. A width of 36 feet when the cows face out is preferable. Greater widths mean uneconomical use of the space. Distribution of the space for these widths is shown in Figure 99. The difference in the widths required when cows face in and when they face out is due to the need for greater widths of the litter alley than for the feed alley. When the cows face out, there is only one litter alley and, therefore, less width of the barn is needed.

The length of the barn is dependent upon the number of head it has to house, the number of cross alleys, the width of the stalls, and the number of box stalls. The desirable dimensions and the factors that determine such dimensions will be discussed in the following:

Stalls. As the requirements for the bull pen and calf pens have been discussed under a previous heading, only the cow stall and the box stalls will be considered here. The width and length of the stall varies according to the size of the cow, the larger cows requiring longer and wider stalls than do small cows. The requirements are set forth in the following table. It will be noted that the extreme variation in the stall widths is 12 inches. It requires approximately 15 per cent greater barn length to house the Holsteins than it would for the same number of Jerseys.

RANGE OF SIZES FOR STALLS SUITED TO THE DIFFERENT BREEDS

Breed	Length				Width			
	Minimum		Maximum		Minimum		Maximum	
	Feet	*Inches*	*Feet*	*Inches*	*Feet*	*Inches*	*Feet*	*Inches*
Ayrshires	4	6	4	10	3	6	4	0
Guernseys	4	6	4	10	3	6	4	0
Holsteins and Brown Swiss	4	10	5	8	3	10	4	2
Jerseys	4	4	4	8	3	2	3	8
Shorthorns	4	8	5	4	3	6	4	0

The stalls should taper from one end of the row to the other, beginning with the longest stalls and ending with the shortest stalls required for the breed.

Depending upon the size of the herd, every dairy barn should be furnished with two or more box stalls to serve as maternity stalls or for sick and injured animals that require greater freedom than the ordinary stall allows. Box stalls should be at least 9 feet square and should preferably be located in one end of the barn. From a standpoint of utilization of space and symmetry of the plans, a good place for the box stalls is opposite the calf pens.

Alleyways. There are three kinds of alleyways in the dairy barn: feed alleys, litter alleys, and cross walks. The feed alley should be at least 4 feet wide where the cows are facing out and 6 feet where they are facing in. Four feet is the minimum width that will conveniently handle feed carts, and 6 feet is generally regarded as the minimum distance cows should be apart when facing each other.

The litter alley is the alley back of the cows. When cows face out, it should be at least 5 feet wide to permit ample room for work and to lessen the soiling of the wall. It is preferable to have an alley 8 feet in width, as this width permits driving the manure spreader through the barn. Except for barns of undue width (41 or more feet wide), an 8 foot alley can be arranged for only when cows face out.

Cross alleys are needed to connect the litter and feed alleys. They should be 4 feet in width to permit the passage to feed carts. While cross alleys should be located at sufficiently frequent intervals to facilitate the work in the barn, care should be taken in not locating too many, as each cross alley takes the place of more than one stall.

Barn floors. The floors of both the alleyways and the stall platforms are of prime importance. The ease with which a barn is kept clean and sanitary and the comfort of the cow are largely dependent upon the type of floor. The alleyway floors should be impervious to moisture, durable, free from crevices where dirt accumulates, and not slippery. Concrete that has been slightly roughened so as not to be slippery, satisfies these requirements better than any other material. If the surface of the concrete is too smooth, the condition may be overcome by sprinkling it with ground limestone before cows are permitted to walk on it. Brick or tile are too slippery when wet to make desirable barn floors. Wood or wood block, likewise, are slippery when wet and soon become unsanitary because of decay incident to the moist conditions of barn floors. Dirt floors are unsanitary under the best of conditions and may become puddled, due to accumulation of water. No absolutely satisfactory material has been developed for stall floors. The requisites of a floor for the stall are that it shall be warm, resilient, impervious to moisture, durable, and not slippery. Concrete is commonly used but it is hard and cold. Wood plank is unsanitary, slippery, and lacks durability. Corkbrick meets the requirements except for durability; it is also costly. Creosoted wood block is used by many and is probably as satisfactory as any, if set in cement to

prevent penetration of moisture between the blocks. Recently several plastic compounds for stall floors have come on the market. Time will be required to establish their merits.

Types of stall stanchions and mangers. All the stalls, stanchions, and mangers may be constructed out of wood. However, this is not desirable because of the lack of durability and the difficulty of maintaining them in a clean and sanitary condition. Iron stalls and stanchions set in concrete with concrete mangers are the most satisfactory and the cheapest in the long run. A large variety in styles of stalls is available on the market. Likewise there are a number of different stanchions that differ in details but are all alike in that they are free swinging, thereby giving considerable freedom of action to the cow.

Light. Sunlight is one of the essentials for a sanitary barn. The direct rays of the sun assist in drying out damp places and have germicidal properties. Windows should, therefore, be of such numbers and so located that the direct rays of the sun will strike every part of the barn. It is generally stated that 4 square feet of glass should be provided for each cow, or 1 square foot of glass for each 20 to 25 square feet of floor space. For a barn 36 feet in width this requirement will be met by spacing 7 feet apart (center to center) windows containing 12 lights of 8 $\times$ 12 inch glass.

In colder climates the amount of glass should be limited to 4 square feet per cow unless double windows are used. This is because glass conducts so much heat out that difficulty will be experienced in keeping the barn warm.

Ventilation. One of the most difficult problems about a dairy barn is that of adequate ventilation. Most barns are wet and unsanitary because of poor ventilation. Kelley states that the purposes of ventilation are to:

1. Supply without draft the fresh air necessary for the health and comfort of cows.
2. Make possible the control of barn temperatures.
3. Preserve the building and feed from mold and rot incident to excessive moisture.
4. Help prevent the spread of disease.

An average dairy cow breathes approximately 116 cubic feet of air per hour, or more than 200 pounds per day. The expired air differs from the inhaled air in these respects: its carbon dioxide content has increased from .03 to 5.53 per cent; its oxygen content has decreased from 20.94 to 14.29 per cent; and its water content has greatly increased. On the average from 12 to 18 pounds of moisture are expelled daily in the exhaled air.

Ordinarily the increased carbon dioxide content of exhaled air is believed to be the cause of the deleterious effects of poor ventilation. This is known not to be the case. The need for ventilation, except in very extreme cases of high carbon dioxide content of the air, is to remove the moisture and bad odors. During the winter, with the barn temperatures around 50° F., practically all the moisture expelled with the exhaled air

condenses in the barn. Effective ventilation removes the moisture laden air before it condenses on the ceiling and walls of the barn. King has shown that it requires an inlet of about 3,600 cubic feet of air per cow to maintain satisfactory air conditions in the barn.

The problem in ventilating is to establish a system that will cause a circulation of the required amount of air. There are two ways in which this may be accomplished: one is to rely upon natural forces to cause air movements, and the other is to use motor-driven fans to force circulation.

The natural forces which are taken advantage of in causing circulation of air are:

1. Difference in temperature between outside air and inside air. Warm air is lighter than cold air and will rise.
2. Pressure of wind on the side of the building.
3. Suction created by wind blowing across a flue. This will draw air out.

Ventilation by means of windows, by the King system, or by the Rutherford system, is dependent upon one or more of these natural forces.

The King system is the most commonly used system of ventilation. It is named after its inventor, Professor King of the University of Wisconsin. It consists, typically of flues extending from near the floor to the top of the barn roof for the outlet of foul air, and air inlets in the ceiling or near the ceiling. The warm air, being lighter than the cold air, will rise in the flue to create a vacuum in the barn; this vacuum pulls in the cold air. While the principle upon which the system is based is the difference in the weight of warm and cold air, it is also influenced by wind pressure. The most essential factor in the successful operation of the King system is the tightness and insulation of the outlet flue. If the outgoing flue leaks air or if the air becomes chilled in the flue, the efficiency of the system if greatly reduced. It is also important that both the outlet and inlet flues be located in the correct places, so that the incoming air strikes the heads of the cows and the foul air is drawn out uniformly. This is illustrated in Figure 100.

The Rutherford system differs from the King system in that the outlet flue opens at the ceiling and the air inlet is at the floor. This system is influenced by the same factors and presents the same problems as does the King system.

The outlet flues should have a cross area of about 1 square foot for each five cows. The inlet flues should be located 7 to 10 feet apart and have an aggregate cross section area equal to that of the outlet flues, except in very cold climates. The inlet flues should have an outside opening several feet below the inside opening to prevent warm air from passing out.

It is obvious that with increased differences in inside and outside temperatures, there will be increased movement of air. On cold days, therefore, too much ventilation is experienced, resulting in too low

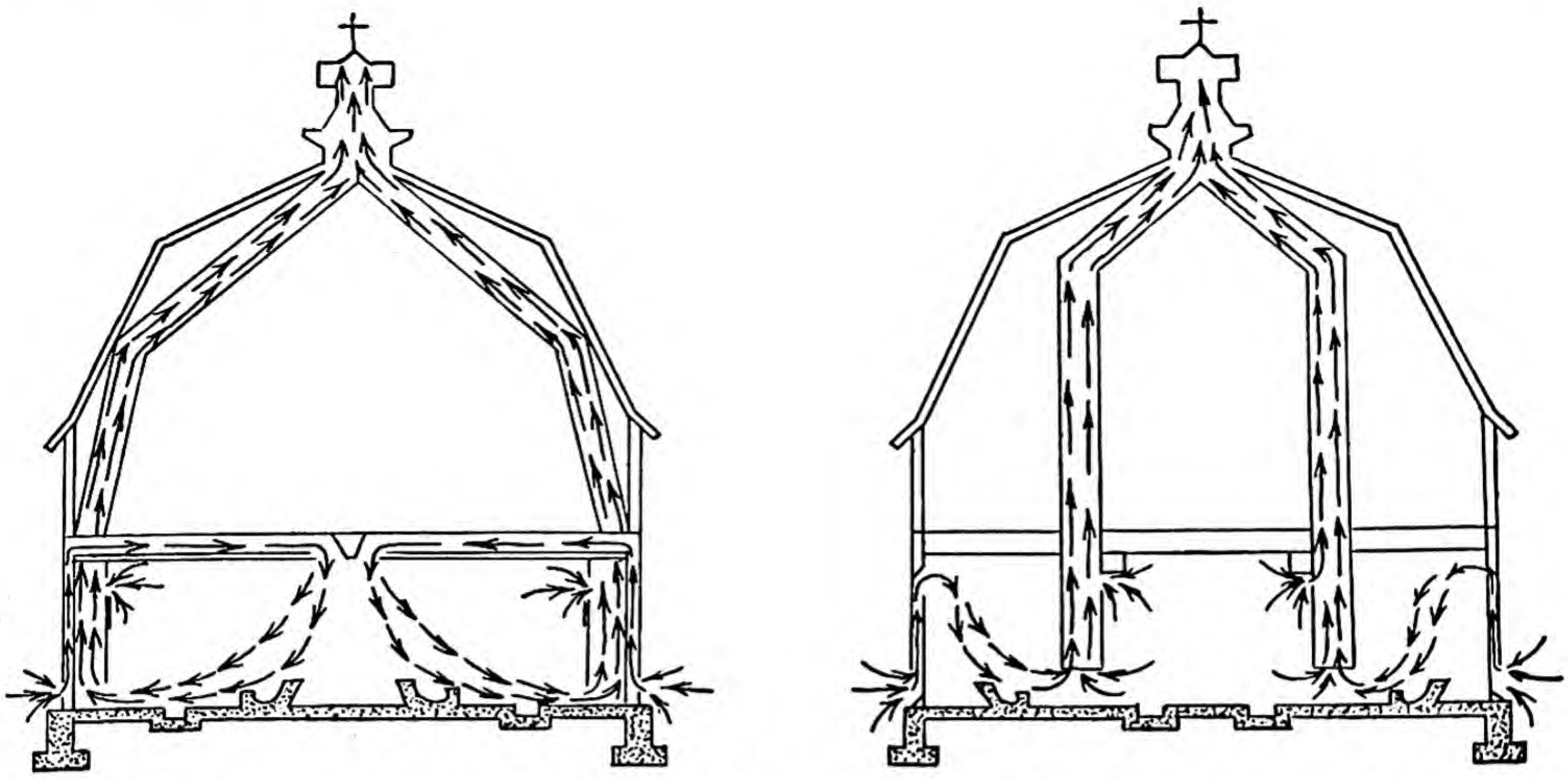

Fig. 100. Illustrating the location of the air inlets and outlets and the resulting air currents, (*left*) when cows face in; (*right*) when cows face out.

temperatures in the barn. Increased wind has the same effect. On mild, still days, the barn will not be ventilated adequately. Overventilation on cold and windy days may be prevented by proper adjustment of dampers placed in either or both the inlet and outlet flues. With changes in temperature or wind, readjustments are needed.

Windows as the only means of ventilation are not satisfactory. They may be valuable auxiliaries to a ventilating system, principally as inlets for air. When used for this purpose, to prevent undue drafts the windows should be fastened with hinges at the bottom and fitted with metal shields on the side, so that when they are tilted out the air must come in over the top of the window. (Fig. 101.)

For adequate ventilation at all times the motor-driven fan is the best. As no expensive flues, either inlet or outlet, are needed, except the opening through the wall for the fan flue, the cost of installation is much less than for the King system. There is, however, the cost of power to run the fan. It is generally considered that when a motor-driven fan is used for expelling the foul air from the barn the naturally occurring openings in the barn are adequate for air inlet.

Other barn equipment. A complete discussion of all the labor-saving devices needed for a dairy barn requires more space than can be given here. The equipment for milking, cleaning the barn, and handling the feed and water, logically would come under such a discussion. Of these, milking machines have been dealt with in Chapter 35, and only the general features of the others will be considered here.

Barn cleaning equipment. The most common way of removing manure from the barn is by means of the litter carrier run on a track suspended from the ceiling of the barn. The suspended track is frequently objected to as a place for collecting dirt. In some cases the track in the

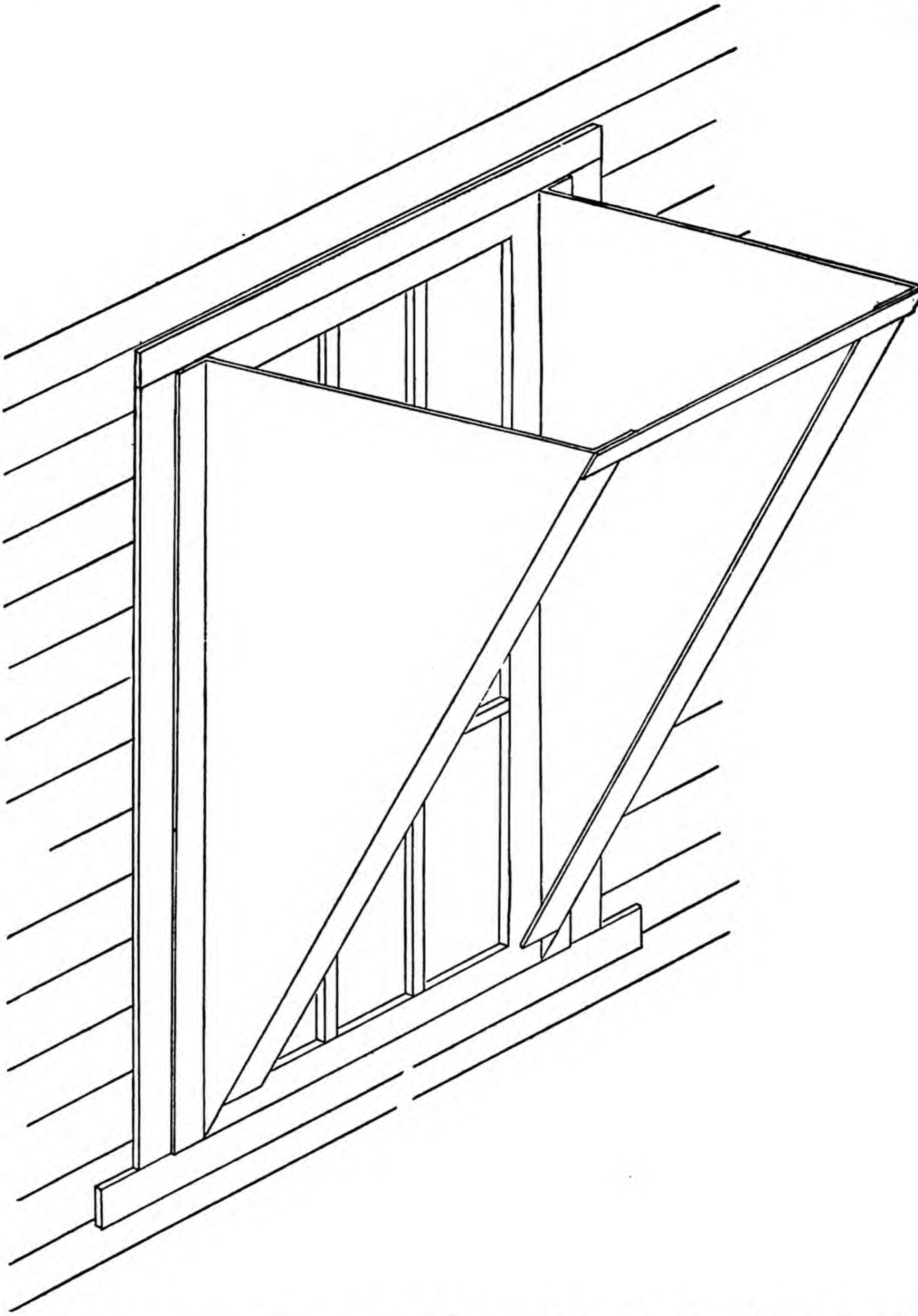

Fig. 101. When windows are used for ventilation they should tip out and be equipped with shields on each side.

barn has given way to carrier trucks or carts upon which the litter carrier is run to the barn door; the carrier is then hoisted on tracks upon which it is carried to the manure pit. In barns where the manure spreader can be driven through, much labor can be saved in handling the manure.

Equipment for feeding. The labor requirement for feeding is a considerable item on the dairy farm, and therefore labor-saving equipment is important. From the standpoint of handling, feeds fall into three groups, hays, silage, and concentrates. These feeds should be conveniently located, and there should be proper facilities for transporting them. Suitable mixing and loading facilities not only save labor, but add materially to the pleasure of working. There is no convenience for the transport of uncut hay, but silage and concentrates may be transported in carts or feed carriers run on an overhead track. In barns with good floors three-wheeled carts with the third wheel swiveled to facilitate turning corners are preferred by most people. The cart for concentrates should be equipped with a spring balance for weighing the feed.

For larger herds the storing and mixing of the concentrates is a problem. The most convenient place for storage is in the second story, where the feed may be mixed in a mixing bin or by a feed mixer; then it is transferred to a hopper with a chute outlet below, from which the feed cart is filled.

Loose housing. The idea of housing cattle loosely in a shed is not new. It has been practiced in various parts of this country and in other parts of the world for many years. There is, however, a renewed interest in this method of handling dairy cattle, one of the major reasons for which is the high cost of construction of the conventional stall and stanchion barn. The disadvantages and advantages of loose housing as well as the numerous problems connected with the construction of suitable buildings or sheds and arrangements for feeding, milking, and loafing areas, together with problems of ventilation need to be given consideration.

Advantages and disadvantages. Although many advantages can be cited in favor of loose housing, there are, six major ones.

1. The structures required for loose housing cost less than the conventional stall and stanchion type of barn.
2. The cows can be made more comfortable and happier under loose-housing conditions than when confined in the stall and stanchion type of barn. They have freedom to move about and, provided that sufficient bedding is used, the bed is always warm.
3. The loose-housing method makes possible a degree of laborsaving that cannot be achieved in the stall and stanchion type of barn. The manure is left to accumulate, preferably throughout the entire season, and the beds kept dry with the addition of suitable bedding. The cleaning of the barn can be done more efficiently when the manure is hauled directly to the field.
4. Loose housing makes feasible the use of the elevated stall milking parlor. This type of milking is far more attractive to workers than the stall and stanchion milking.
5. The loose-housing system, where the manure pack accumulates throughout the housing season, affords conservation of that product that is not attained under the conventional stall and stanchion barn.
6. One of the most important features of the loose-housing method is the increase in milk production of some 5 to 10 per cent over those animals housed in the stall and stanchion type of unit.

To counteract, in part at least, these advantages there are some disadvantages.

1. Loose housing requires from 50 to more than 100 per cent more bedding than stall and stanchion housing.
2. Because of the large bedding requirements, too often cows become more dirty in the loose housing method than when kept in stalls and stanchions.
3. There is a little evidence to indicate that loose housing may be conducive to the spread of some infectious diseases, once these gain entrance to the herd. However, this danger is not greater than that which occurs from keeping cows in small yards.
4. Loose-housing systems require considerable more floor space in total when the milking-parlor requirements are taken into consideration than is necessary for the conventional stall and stanchion housing.

Suitable structures for loose housing. The type of structures that will satisfy loose-housing conditions will vary with climatic conditions. In the more moderate climates all that is required is a shed that has sufficient space between the floor and the ceiling to provide for a sufficiently deep manure pack and that is opened to the south. In the more severe climates it is necessary that four walls be provided. However, it has been found that it is not necessary to build warmly. The chief objective of the loose-housing structure in severe climates is to prevent direct cold drafts. The temperature of the surrounding air may drop to even below zero without creating discomfort to the cows, provided they are dry and free from drafts. Under properly managed loose-housing conditions, the bed will always be warm from the fermentation taking place in the manure pack.

Because of the advisability of letting the manure accumulate throughout the entire housing season, in northern climates provisions must be made for sufficient heights from the floor to the ceiling to allow for at least three feet of manure pack. Therefore, not less than nine feet is required from the floor to the ceiling. It has been reported that if the cows have free access to the outside it is necessary that the loose-housing shed be well lighted. Animals have been found to prefer chilly weather to a dark shed.

There is still considerable discussion as to the amount of floor space required per cow under the loose-housing system. The required area per cow is dependent upon the climate, the size of the cow, and production level. In milder climates cows will need to be in the loafing area a shorter time; consequently, less space is required. It is obvious that the larger cows will require more space than smaller ones, and high producing cows eat and drink a good deal more than low producing cows and thus will void more feces and urine. The floor space for the loafing area recommended by a committee in the North Central states is from 50 to 100 square feet per cow in the loafing area.

Feeding. Under the loose-housing system hay and silage are generally fed *ad libitum* while the grain, because of the variations in the individual requirements, is fed in the milking parlor or by some other method. Although some people feed hay and silage from bunks located in the loafing

area, this method has generally been found unsatisfactory. A more satisfactory way of feeding hay and silage is by having a special feeding area which, in more moderate climates, may be outside the loafing shed. In the more severe climates it is well to make provisions for feeding under protection. One of the most satisfactory methods found is that of providing a paved area, preferably along one wall, in which the manger and hay racks are placed, allowing at least two linear feet per head. A paved area extending back from the manger for about eight feet has been found to be satisfactory. This area is not bedded and should be cleaned out periodically. Such a feeding area has the advantage that a good proportion of the total feces and urine are voided while feeding and if removed, periodically, will conserve materially on the straw requirements.

Ventilation. One of the major problems in loose housing is that of adequate ventilation. For the most part, loose-housing sheds have an opening to the outside at all times to permit the animals to go in and out at their pleasure. This makes unworkable any conventional ventilating system. Openings in the two ends of the barn or shed permitting a free flow of air have been found to be most satisfactory in overcoming the undesirable wetness of condensation of moisture.

Provision for calves and maternity pens. Under the loose-housing system the calves and maternity stalls may be provided for in a separate building or in the loose-housing area. The floor is dirt, and posts may be driven in so as to make stalls and pens for whatever needs may arise. As the need for these stalls decrease, they may be removed, thus increasing the loafing area. The question as to whether the floors should be paved in the loafing area is subject to debate.

Providing for feed storage. If the loose-housing unit is a two-story building, hay may be stored above, as in the conventional stall and stanchion barn, but provision should be made whereby it can be introduced to the feed rack with the minimum of labor. If the housing shed is of the single-story type, then provision for the hay storage should be made so that it is expedient to the place where it must be fed. It is also important that the feeding area be in direct line with the silo so that proper conveyances can carry the silage direct from the silo to the mangers. If grain is to be fed in the milking parlor, the best solution of the grain feeding problem is to make provision for the storage of the grain above the milking room, into which it is conveyed by gravity.

When provisions are made for storing the grain overhead, its feeding can be made easy by appropriate feed conduits from the feed storage bins above the manger located in the front of the milking stall.

Milking parlors. Milking parlor is a name used to designate a special room in which cows are milked. Interest in milking parlors is very much on the increase and will continue to be so with the extension of the loose-housing idea. There are two general types of milking parlor: one in which loose stalls are on floor level and another in which the milking stalls are elevated thirty inches above the floor from which the operator works. In connection with loose housing a milking parlor or milking room of some

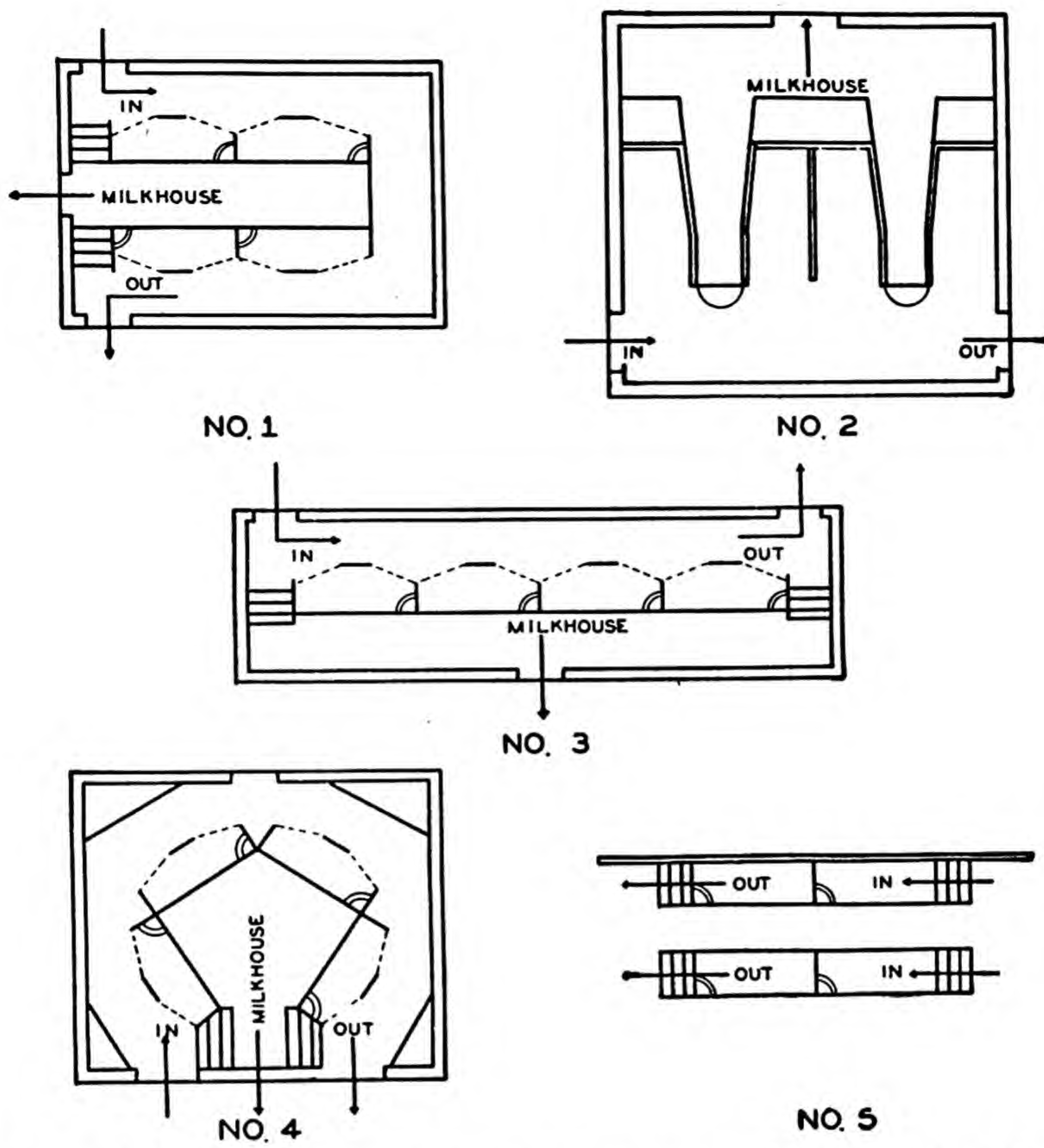

Fig. 102. Different arrangement patterns of elevated milking stalls: No. 1. U type. No. 2. Montana type. No. 3. Tandem type. No. 4. Semicircular type. No. 5. Double-tandem type.

sort is essential. It has certain advantages over the stall and stanchion type of barn: there is a smaller area to be cleaned and less work is required in the actual milking, since fewer steps are required. Instead of the milker carting all utensils required for milking to the place where the cow is stalled, the cow comes to the milker. While milking parlors are generally associated with the loose-housing method, some installations are made where cows are kept in the conventional stalls and stanchion barns. Many of the advantages of the milking parlor are lost in the extra amount of labor required in releasing cows from the stanchion, bringing them back, and cleaning the walks and alleys thereby traversed. One of the chief disadvantages of the milking parlor is the high cost of construction to cover the extra space required.

The floor-level stall type. There are two types of floor-level stalls. One is the regular stall and stanchion into which the cows are brought and, when milked, backed out of. Generally the manger is used for the feeding of grain during the milking. The second kind of floor-level stall is what is

known as the walk-through stall. The cows enter from one side, and when milking is done, the gate is opened and they walk through to go back to the yards or the barns. From three to six or more stalls are used in the floor-level stall type, the number that can be accommodated at one time being dependent upon the number of cows in the herd and the number of people doing the milking.

Elevated stall type. The elevated stall type of milking parlor is the most popular in this country because of the ease with which the milking can be done. When the stalls are elevated 30 inches above the floor from which the operator works, no stooping is required in attaching the milking machine or in washing the udder. Since the cows do not at any time enter the pit from which the milker operates, it is never soiled from the source. There are several types of arrangement of the elevated milking stalls, the one to be preferred depending upon local conditions.

For efficient operation even though there is but one milker, four stalls should be used. This allows two cows to milk simultaneously while the other two are being prepared for milking. By this arrangement sufficient time will also be allowed for the cows to eat their grain, except in cases where cows are slow eaters and large amounts of grain are offered. The five general types of elevated stall arrangements are illustrated in Figure 102. They are the tandem type, the U type, the Montana type, the semicircular type, and the double tandem type.

It has been found that to be satisfactory a stall should be eight feet in length, three feet in width at the widest portion, and not less than two feet wide at either end. In those types where the cows pass by the milking stalls an alleyway three feet wide is required. Stalls in which milking parlors are made by a number of manufacturers of milking and barn equipment may vary somewhat in detail. The general principle, however, in all of these types is essentially the same. The gates are opened and closed by the operator by means of levers. Likewise the door from the pens or barns is operated from the milkers pit to let in the cows.

The milking stalls should be provided with drainage facilities and a curb 2½ inches high should be constructed from the stall floor on the edge next to the milking pit to protect soilage of the pit in the event that urination or defecation should occur. The milking parlor lends itself admirably to the use of the releaser type of milking equipment; however, any other standard milking machine may be used.

Feeding grain. In some cases where milking parlors are used special stalls are arranged in which cows can be fed grain before they enter the milking parlor, on the theory that the feeding of grain adds to the danger of contaminating the milk. In most installations, however, grain is fed in the milking stalls in a small manger located in the front side of the stalls. As previously described, grain feeding may be made a simple matter in the milking parlor by proper construction and storage of the grain up above. In average milking herds cows will be in milking stalls at least eight minutes for each milking. This allows them time enough to eat the normal grain allowance. However, some cows eat grain more slowly than

Fig. 103. The elevated milking stall commonly used in the so-called milking parlor makes the milking job easier and more attractive.

others and if such slow eaters should also be heavy producers requiring extra amounts of grain, the normal time that they are in the milking parlor may not be long enough for them to absorb the amount of grain desired.

When grain feeding is done in the milking parlor along with the washing and the preparation of the cow for milking as well as the actual milking, the whole operation can be performed by one individual. If grain is fed before the cows enter the milking parlor (unless it is done some time before milking), it will be more difficult for one man to handle the entire operation. There is another distinct advantage to feeding grain in the milking parlor: it offers a special inducement for the cows to come into the parlor.

Training cows to enter milking parlors. One of the important aspects of parlor milking is that of having the cows come in of their own free will and to be at ease during milking time. In order that the cows meet these requirements it is important that proper precautions be taken when they are first introduced to the set-up. If cows are roughly handled and forced into the milking parlor the first time, they are apt to form a bad association with the set-up and will be hesitant to come in of their own will and, when in the stalls, are apt to be so excited that the milking cannot be accomplished properly.

It has been found that if the milking stalls are left open, grain put in, and the cows permitted to go through several times before the actual milking starts, there will be less difficulty in forming a desirable association with the set-up. Usually if the boss cow takes it upon herself to go through, the rest of them will follow without a great deal of difficulty. Once the cows have developed a liking for the milking parlor, they will line up in essentially the same order for each milking and will enter the parlor of their own accord as soon as the door is opened. In some herds the cows in the lower herd level have to be give some special inducements to come in.

Behavior of cows in milking parlors. Once the cows have been properly trained to be milked in the milking parlor, they feel equally at ease therein as in the normal stalls and stanchions. While provision should be made for drainage from each stall, it has been found that cattle very seldom urinate or defecate in the milking stalls. These physiological activities usually take place while the cows are waiting to come into the milking set-up. In one herd of 19 cows it was found that, on the average, one

defecation in the milking stall occurred each week. The individual that was guilty of the performance was rather nervous, particualrly when strangers were around.

Holding alleys. One of the important adjuncts for the successful operation of the milking parlor is a holding alley three feet wide that will accommodate three or more cows. This alley should extend to the yard or loose-housing system. This permits the cows to organize themselves before they come up to the door letting them into the milking stalls. Unless there is such a holding alley, contests may occur just before entry into the parlor.

Chapter 40

BARNYARD MANURE

WHILE BARNYARD MANURE SHOULD BE CONSIDERED AS ONE OF THE VALUable returns from the dairy, it is probably the least appreciated and the most abused commodity produced on the farm. One of the very important agricultural problems is that of maintaining the fertility of the land. This can be done by the use of livestock when the manure is properly cared for and returned to the soil. Because of the poor care given manure, a large portion of its fertilizing value is lost before it reaches the land. The poor treatment given manure is due to a lack of knowledge of its value and ignorance as to factors causing deterioration.

Fertilizing value of crops and feeds. When crops are sold from the farm, valuable fertilizing constituents are removed that must sometimes be restored by the purchase of commercial fertilizers. While there are about 15 chemical elements used by plants, only three—nitrogen, phosphorus, and potassium—are as a rule removed in sufficient quantities to reduce the fertility of the soil. The amounts of these constituents and their values per ton for various crops, concentrates, and animal products are given in the table on page 451. Except for the legumes, when crops are sold from the farm the amounts of the element which each feed contains are removed from the soil. If the legumes have the proper bacteria, they fix nitrogen from the air. The legumes, too, have the highest fertilizing value, largely because of the high nitrogen content. By growing legumes and feeding them to livestock the nitrogen content of the soil may be increased if the manure is returned to the soil. In order to maintain the soil fertility when crops are sold from the farm, it will require the expenditure of money for fertilizer equal to the values set forth in the table.

If livestock is produced from the crops, the amounts of fertilizing constituents removed are much less. The fertilizing value per ton of livestock and crops are about equal, while it takes many tons of crops to produce one ton of meat. When milk is sold, only one-fifth of the fertilizing value is removed as when an equal amount of alfalfa is sold. When butter is sold, practically no fertilizing value is removed.

In most cases the dairy farmer purchases some high protein concentrate. Reference to the table on page 451 shows that the more common of these feeds contain much larger amounts of the important fertilizing constituents than do the ordinary farm crops. The fertilizing value of these feeds forms a good proportion of the purchase price. By use of these concentrates not only is the ration improved, but valuable fertility is added to the farm.

Composition and value. The composition of manure varies with the class of animal, the kind and amount of bedding used, the kind of feed that is fed, and the care given the manure. A mature animal on a main-

tenance ration returns in the manure practically all of the phosphorus and potassium and about 95 per cent of the nitrogen in the feed. The growing animal takes out varying proportions of nitrogen and phosphorus for the building of body proteins and bony structure, and smaller amounts of

FERTILIZING CONSTITUENTS PER TON OF VARIOUS CROPS, ANIMAL PRODUCTS, AND COMMONLY PURCHASED CONCENTRATES [1]

	Constituents per Ton			Fertilizer Value
	Nitrogen	Phosphorus	Potassium	Per Ton
Crop	*Pounds*	*Pounds*	*Pounds*	*Dollars*
Alfalfa	47.5	4.8	37.5	8.50
Barley	36.5	7.3	8.9	5.75
Barley straw	12.0	2.0	23.0	3.04
Bluegrass, Kentucky	26.5	4.8	35.0	5.83
Clover, red	42.0	5.0	25.5	7.14
Corn	35.5	5.0	6.6	5.23
Corn silage	6.9	1.4	8.3	1.49
Oats	43.8	7.5	9.5	6.68
Oat straw	12.0	2.0	28.4	3.37
Timothy	20.0	2.8	2.3	2.92
Wheat	39.5	7.2	8.3	6.06
Wheat straw	10.0	1.6	10.3	2.00
Purchased Concentrate				
Bran wheat	50.6	26.4	24.8	10.57
Cottonseed meal (43% protein)	138.2	22.2	27.2	20.75
Linseed oil meal	112.2	17.2	25.4	16.95
Soybean oil meal	141.8	13.2	44.0	21.16
Gluten meal	137.2	7.2	.4	17.31
Animal Products				
Milk	11.2	1.8	2.8	1.72
Cheese	90.0	7.30		
Butter	2.5	0.4	0.2	0.36
Fat steer	51.2	11.8	2.8	7.66
Fat pig	46.4	7.4	2.6	6.57

potassium. The milking cow needs larger amounts of all of these elements for the production of milk. According to Wells and Dunbar, dairy cows retain 30 to 40 per cent of the nitrogen and 40 to 60 per cent of the phosphorus consumed in the feed. The kinds of bedding affect the composition of the manure to the extent of the amounts used, and the composition. When shavings are used for bedding, no manural value is added. Oat straw (see the preceding table) has more than 50 per cent greater fertilizing value than wheat straw.

[1] The bases for the calculations of fertilizing constituents in purchased concentrates are from Morrison. Nitrogen is valued at 12 cents, phosphorus at 11.4 cents, and potassium at 6 cents per pound.

The kind of feed is an important factor affecting the value of manure. Feeds high in phosphorus content, such as bran, cottonseed meal, and linseed oil meal, produce manure proportionately higher in these constituents. The higher the nitrogen content of the feed, the higher the nitrogen content of the manure.

On the average, according to Morrison, about 80 per cent of the fertilizing value of a feed is excreted in the feces and urine. The following figures, taken from Ames and Gaither, are based upon manure from average feed, and represent the amount per ton: nitrogen, 11.40 pounds, phosphorus, 2.0 pounds, and potassium, 10.4 pounds. With nitrogen at 12 cents a pound, phosphorus at 11.4 cents a pound, and potassium at 6 cents a pound, a tone of manure has a value of $2.22. The manure from an average cow for a year would have a fertilizing value of more than $30.00, to say nothing of the value as a source of organic matter. The manure value of a feed is, therefore, 80 per cent of the fertilizing value of the feed.

Amounts of manure produced. The amount of manure produced by a cow varies with the amount of feed consumed and the bedding used. Jensen gives 12.5 tons and Van Slyck 15.0 tons as the average annual production per cow. These figures include the urine, which contains about one-half of the nitrogen and two-thirds of the potassium. Young stock and dry cows produce less in proportion to the lesser amount of feed they consume. A dry cow weighing 1,000 pounds produces about one-half as much manure as a cow of the same weight producing 50 pounds of milk daily.

Losses in manure. Under average conditions large proportions of the fertilizing value of manure are lost. A number of experiments have shown that large losses are due to loss of the liquid manure, leaching, and fermentation. The liquid manure contains about one-half of the nitrogen and two-thirds of the potassium, and its complete loss would reduce the manural value by that amount. The liquid manure may be saved by the use of adequate bedding to effect complete absorption, or by draining into an underground storage tank. The latter is a common practice in Europe, where the liquid manure is highly valued.

Exposing manure to ordinary leaching for 109 days in New Jersey caused a loss of 38 per cent of the nitrogen, 52 per cent of the phosphorus, and 47 per cent of the potassium. When exposed for five months over 50 per cent of the fertilizing value of the manure was lost.

Bacterial decomposition of manure causes heavy loss of the nitrogen, which escapes into the air in the form of ammonia. In decomposing compost, the odor of ammonia can be readily detected. Fermentation, deleterious to manure, cannot take place in the absence of air. Loosely stored and too dry manure contains enough air for rapid decomposition. In extreme cases the manure becomes "fire fanged"; it assumes a gray color and becomes dusty. All of these fermentations are accompanied by heat.

Preventing losses in manure. To stop losses in the fertilizing value of manures, one must stop the leaching, save the liquid manure, and prevent

excessive fermentation. To prevent leaching, the manure may be hauled out and spread on the land daily. On level ground, this method insures getting the maximum fertility of the manure onto the soil. On hilly lands, however, when the ground is frozen, the fertility of the manure is leached out and washed down the slopes. For this reason, and also because it is not always convenient to haul the manure out daily, it becomes necessary to store manure for varying lengths of time.

To properly prepare manure for storage enough bedding should be used to absorb the liquid manure, but not so much that the manure becomes too dry or "fire fanging" will result. A manure pit should be used, with a concrete floor to prevent drainage of the liquid portion and a roof to prevent washing by rains. The next important step is to pack the manure to prevent fermentation by excluding the air. Under these conditions, manure may be stored without any loss of potassium and phosphorus, and the nitrogen losses may be reduced to 20 per cent. The sprinkling of acid phosphate on the manure increases the phosphorus content of the manure and helps to reduce the nitrogen losses.

When cattle are permitted to run loose in the barn and the manure is permitted to accumulate, the least possible loss of fertilizing constituents is experienced. When the barn is well bedded, a clean and dry place may be maintained for the cattle. Tramping by the cattle keeps the manure well packed and there is no chance for leaching.

Bedding. Bedding is used for two reasons: to provide comfort for the animals and to keep them clean. For sanitary reasons in the production of milk, the bedding should be clean and free from mold and dust. The choice of bedding for cows will depend upon what material is available, its cleanliness, and its water absorbing properties. When bedding is purchased, other things being equal, the choice should be guided by the cost per unit water absorption. The following table lists the water absorbing capacities of various materials used for bedding. It will be noted that dried peat moss has the greatest water absorbing capacity, with flax straw next and the cereal straws and stover third. Among the straws, oat straw is superior to wheat straw. Shavings and sawdust have the lowest water absorbing capacities and also possess great variability.

WATER ABSORBING CAPACITIES OF VARIOUS BEDDING MATERIALS

Material	Pounds Water Absorbed by 100 Pounds of Bedding
Wheat straw	210
Cut wheat straw	200
Oat straw	250
Cut oat straw	244
Shavings	119 to 220
Sawdust	80 to 160
Flax straw	Greater than cereal straws
Shredded stover	250
Dried peat moss	500 to 1,000

In addition to the materials listed, peanut hulls, cocoa shells, oat hulls, cottonseed hulls, and various other materials may be used for bedding. The hulls have about the same water absorbing capacities as the straws, but they are not as well suited for bedding in stalls because they are difficult to keep in place.

Amounts of bedding. The amounts of bedding needed depend upon the kind of bedding, the size and productivity of the cows, and the condition under which it is used. As the amount of bedding used depends upon its water absorbing qualities, variations are inversely proportional to the water absorbing capacities. For average cows, four pounds of shredded stover or five pounds of wheat or oat straw are needed daily. For high producing cows there is a marked increase in the daily water eliminated, and as much as 50 per cent more bedding is needed.

When cows run loose, from 50 to 100 per cent more bedding is needed than when they are kept in stalls and stanchions. Cows in box stalls likewise use more bedding.

Chapter 41

FEEDING DAIRY CATTLE

To SECURE HIGH MILK PRODUCTION COWS MUST BE USED THAT HAVE INherited capacities for high production, and they must be fed and cared for in such a way as to bring out the inherited potentialities. No matter how good the inherent capacities of a cow may be, unless she is properly fed she will not be a high producer. Whether improved breeding or improved feeding is the more important in increasing the average production of the cows in the United States is debatable. There is no doubt, however, that by improved feeding methods the average production of cows can be greatly increased.

Why milk cows should be so commonly malnourished because of insufficient quantity of feed is difficult to conjecture, unless it is due to a lack of understanding of the requirements of cows. Why milk cows are frequently malnourished because of deficiencies in one or more of the many dietary essentials is more easily understood. There are so many dietary essentials that must be supplied for an adequate ration that it is not hard to understand that the layman may find difficulty in comprehending all of the needs.

In order to be able to feed cows for the most economical production one must first have a conception of the uses to which feed is put by the animal. After that, he must know the needs of the animal in terms of the different dietary substances, and then he must know the values of the different feeds in supplying the requirements. It is possible to furnish a ration that theoretically supplies all the dietary essentials but still is unsuited for the cow. The mixture may be unpalatable or too bulky, either of which may result in the cow not being able to consume enough feed to obtain the necessary nutrients. The ration, too, may be toxic or otherwise have a deleterious effect upon the cow. Lastly, the cost of the ration must also be considered.

From the foregoing it is obvious that the proper feeding of dairy cattle is not a simple matter but requires a knowledge of many fundamentals that will enable one to properly put together and supplement feeds at hand.

What food is used for. That all animals must have food or they will soon die is common knowledge. Just what the food is used for and what proportions are used for each of the various animal activities is not generally known although there is a great deal of information available on the subject. The dairy cow needs food at one time or another for the following:

1. Growth and development of body tissues
2. Production of energy for body temperature and muscular activity

3. Maintaining and repairing body tissues
4. Production of milk
5. Development of the fetus

These may be divided into two groups, the requirement for maintenance and the requirement for production. The requirements for maintenance include the needs for the repair of worn-out body tissues, and for the production of heat and energy to maintain the body temperature and the necessary muscular activity. Under the requirements for production are the needs for growth, milk production, and development of the fetus. The requirements for maintenance are high and constitute an overhead of tremendous importance in dairy farming. Whether a cow produces milk or not, the amount of feed needed for maintenance is constant. For average dairy cows about one-half of the feed is used for maintenance and the other half for production.

Nutritional requirements. The production of milk is a very highly specialized function of the cow; therefore special attention must be given to furnishing the dietary requirements. There are specific minimum requirements of each of the several dietary substances. If the ration is deficient in any one of these essential dietary substances the milk production will be lowered regardless of how much feed is offered or how adequate the ration may be in all other respects. Some of the dietary essentials, particularly the vitamins, minerals, and energy in the form of fat and glycogen, may be stored in the animal body. A ration deficient in any one of these may then prove adequate until such time as the body stores are depleted. Cows may therefore produce well for a time on a deficient ration.

The essential dietary substances needed are:

1. Energy producing foods
2. Proteins
3. Minerals
4. Water
5. Vitamins

The first two of these requirements are usually referred to as digestible protein and total digestible nutrients.

Digestible nutrients. While all of the dietary essentials are nutrients, the term *nutrients* as commonly used in dairy cattle feeding refers only to the proteins, carbohydrates, and fats. Feeds vary greatly in their nutrient content and are sometimes classified upon the basis of the protein content, such as high, medium, and low protein feeds. The analysis of feeds, as determined by the chemist, includes crude protein, ether extract or fat, nitrogen-free extract, crude fiber, and ash. Of these the nitrogen-free extract and fiber constitute the carbohydrates.

Not all of the nutrients of feeds are digestible. The portion that is digestible is determined by feeding trials in which the nutrients of the feeds taken in and the amounts in the feces are determined chemically. The difference constitutes the portion digested, and the per cent of any one nutrient digested is known as the coefficient of digestibility or the digestion

coefficient. The digestible nutrients are reported in two terms, digestible crude protein and total digestible nutrients. The digestible crude protein is the number of pounds of digestible crude protein per 100 pounds of the feed stuff. The total digestible nutrients are arrived at by adding the pounds of digestible crude protein, the pounds of digestible carbohydrates, and 2.25 times the pounds of digestible fat per 100 pounds of the feed. The total digestible nutrients represent approximately the energy value of a feed. The protein yields approximately the same energy as carbohydrates do, while fat yields 2.25 times as much when these nutrients are burned in the body.

Different feeds vary greatly in their total digestible nutrient values, as do the coefficients of digestibility. In the main, increasing fiber content of feeds is accompanied by a decrease in the coefficients of digestibility, with resulting lower total digestible nutrients. Most concentrates have 75 or more pounds of digestible nutrients per 100 pounds, while roughages average about 50 pounds per 100 pounds of weight. Fiber not only has a low coefficient of digestibility but also depresses the digestion coefficient for protein.

Net energy. Feeds may be measured by the amount of energy they will produce upon burning. The common measure is the therm (T). A therm equals 1,000 calories, or the amount of heat required to raise 1,000 kilograms of water 1° C. or to raise 1,000 pounds of water 4° F.

The net energy value of a feed, as the term implies, represents that portion of the energy which is digested and available for the use of the animal body less the losses and energy required for digestion. In the mastication, digestion, and metabolism of feeds there are losses and energy used which are not taken into account by feeders when measuring out the digestible nutrients. To secure the net energy value of a feed the following must be subtracted from the gross energy of the feed:

1. The losses of undigested material in the feces
2. The energy required for mastication and digestion
3. The losses of gases in the digestive tract
4. The losses in the urine, chiefly urea

The losses of energy producing material in the feces is taken into account in determining the total digestible nutrients. The other subtractions from the total energy of a feed to ascertain the net energy are not considered in determining the total digestible nutrients. Inasmuch as feeds vary greatly in the amounts of energy required for digestion and mastication and that are lost in gas and urine, the difference between the net energy values and the total digestible nutrient values of feeds also varies greatly. From the following table it will be noted that the pounds of total digestible nutrients and therms net energy are approximately the same for the concentrates. For alfalfa hay, timothy hay, and wheat straw the therms net energy are 82, 75, and 28 per cent respectively of the values of pounds of digestible nutrients for the same feeds. The relatively lower net energy values of

roughages as compared with concentrates are due to the additional energy needed in the mastication and digestion of the roughage.

COMPARISON OF TOTAL DIGESTIBLE NUTRIENTS AND THERMS NET ENERGY PER HUNDRED POUNDS OF FEEDS

Feed	Total Digestible Nutrients	Net Energy
	Pounds	*Therms*
Corn	80.6	79.2
Oats	71.5	71.3
Barley	78.7	79.2
Alfalfa hay	50.3	41.5
Timothy hay	46.9	35.2
Wheat straw	35.7	10.0

The loss of energy in the urine is limited mainly to urea, an end product of protein metabolism.

While the net energy values of a feed represent more nearly what the animal will get out of the feed for production purposes, they do not necessarily represent the feed value for maintenance. The heat generated from digestion is used in warming the animal body, and in cold weather it reduces the maintenance requirements. In warm weather, however, the heat of digestion must be gotten rid of.

For practical purposes the use of total digestible nutrients is satisfactory when it is remembered that more total digestible nutrients are required in roughage than in concentrates.

Energy may be stored throughout the body in large quantities in the form of fat and in a smaller quantity in the liver and muscles in the form of glycogen. Carbohydrates, fats, and proteins of the feed may be the source of the body stores. The carbohydrates and most of the protein may be converted into fat.

Fat. While fat may be produced in the body from carbohydrates and protein, there is some evidence that a minimum amount of fat in the ration is essential and that some of the more highly unsaturated fatty acids, such as linoleic and linolenic, must be supplied in the feed. Maynard has shown that cows fed a ration from which the fat had been extracted, but which otherwise supplied the nutritive requirements, failed to maintain milk production as well as those fed the ration containing the normal amounts of fat. Allen has reported increased fat content in milk from cows fed additional amounts of fat. This indicates that at least some fat in the ration is needed for the best results. Normal rations, however, probably contain the necessary amounts of fat.

Protein. Protein is needed by the animal for the growth and maintenance of the body tissues, for the production of milk, and for the fetus. While any of the nutrients may be the source of energy, the animal is unable to produce its needed protein from anything but protein in the

feed. The feed must not only supply the protein, but in order for the protein to be adequate, it must also contain certain amino acids. Some of the amino acids required by the animal body may be formed from other amino acids, but others, known as essential amino acids, cannot be produced by the animal and must be present in the feed. Many plant proteins are deficient in one or more of the essential amino acids; and when the ration is restricted to such plants, it will be found inadequate.

Many plants supplement one another in the essential amino acids; this is one of the reasons that a ration consisting of a variety of plants is desirable.

Minerals. Mineral matter, although needed in much smaller quantities, is as essential for growth, maintenance, and production as are the organic food materials. While the need for minerals in the animal body has been known for a long time, only recently have mineral deficiencies been discovered in what were considered normal rations. The list of known required mineral elements has been growing, and it is probable that further additions may be made of some elements that are needed in only small amounts. At present the following mineral elements are known to be needed: sodium, potassium, chlorine, calcium, phosphorus, magnesium, iron, copper, iodine, sulphur, manganese, and cobalt. Zinc is always found in animal bodies, but whether it is essential is not known. Fluorine, likewise, is always present; some claim that it is essential for the formation of dentine in the teeth.

The functions of minerals in the body are many and complex, and many are little understood. The bony framework consists principally of calcium and phosphorus. The blood depends upon sodium chloride, potassium chloride, and calcium chloride to maintain its osmotic pressure and equilibrium. Hemoglobin formation needs iron, copper, and possibly cobalt. Gastic digestion depends upon hydrochloric acid, of which the chlorine comes from the chlorides. Iodine is needed for the formation of thyroxin. In addition the body cells need a delicate balance of various mineral elements for their proper function. Some of the mineral elements combine with organic substances to form compounds essential to the animal organism. Numerous other functions and interrelationships of mineral matter in the animal body could be cited, but space will permit only a brief consideration of the needs and supply of the more important minerals from a practical nutrition standpoint.

Sodium chloride. Natural feeds for cattle are universally deficient in sodium chloride or common salt. If cattle are not given common salt, they soon become affected. The lack manifests itself first in an unusual craving for salt and later in a complete breakdown and ultimate death. The salt requirements vary with the size of the cow, the type of ration fed, and the amount of milk produced. Babcock and Carlyle stated that for normal rations 0.75 ounce of salt is needed daily for each 1,000 pounds of live weight and an additional 0.3 ounce for each 10 pounds of milk produced.[1]

[1] Babcock and Carlyle. Wis. Report. 1905.

The best way of furnishing salt is to allow free access to salt placed in cups in the barn or in a box protected from rains in the yard. A portion of the salt requirement may be furnished in the grain by mixing in one pound of salt for each 100 pounds of grain mixture. In addition to supplying some of the salt requirements the palatability of the grain mixture is improved by this procedure. If salt cups are not available, salt should be given milking cows every other day; and dry cows and young stock should receive salt twice a week.

Young stock and dry cows may be furnished salt in the form of blocks. Milking cows, whose salt requirements are higher, should have the salt furnished in the granulated or flaked form.

When cattle have not had salt for long periods of time, free access to unlimited amounts will lead to excessive consumption, which sometimes results in death to the animals.

Calcium and phosphorus.[1] Over 75 per cent of the total mineral matter of the body, 90 per cent of the minerals of the skeleton, and about one-half of the mineral matter of milk are calcium and phosphorus. It is therefore apparent that next to sodium chloride these two minerals are needed most abundantly in the ration. Since about twice as much calcium as phosphorus is needed, the ideal ratio is two parts calcium to one part phosphorus. However, at least when adequate vitamin D is present, the ratio may be much wider provided that the minimum requirement is furnished.

The calcium and phosphorus contents of the more common feeds are given in Table IV of the Appendix. It will be noted that different feeds differ greatly in their contents of these two minerals. In general, roughages are high and concentrates are low in their calcium content. For phosphorus the reverse is true. Variations within these groups are large. The legumes contain several times the amount of calcium that the nonlegumes do. Cottonseed meal, wheat bran, and linseed oil meal are much higher in their phosphorus content than are the grains. Both the calcium and phosphorus contents of feeds vary because of the soil conditions upon which they are grown. Hays grown on an acid soil are much lower in calcium than those grown on alkaline soils. Soils deficient in phosphorus produce feeds much lower in their contents of phosphorus. Large areas in various parts of the world have soils so deficient in phosphorus that the feeds grown thereon are deficient in phosphorus for the normal nutrition of cattle.

Calcium or phosphorus deficiency, or lack of sufficient vitamin D, produces in young growing cattle a disease known as rickets. The joints of animals so affected become swollen and sore, causing them to move stiffly. They usually stand with the legs drawn well under the body and the back humped; and when walked, they act as if they were in great pain. (Fig. 104.) If the condition is due to a deficiency of phosphorus, a depraved appetite develops; the animals will chew wood, bone, and other material.

[1] Eckles, Gullickson, and Palmer. Minn. Agr. Expt. Sta. Tech. Bul. 91. Huffman, Duncan, Robinson, and Lamb. Mich. Agr. Expt. Sta. Tech. Bul. 134.

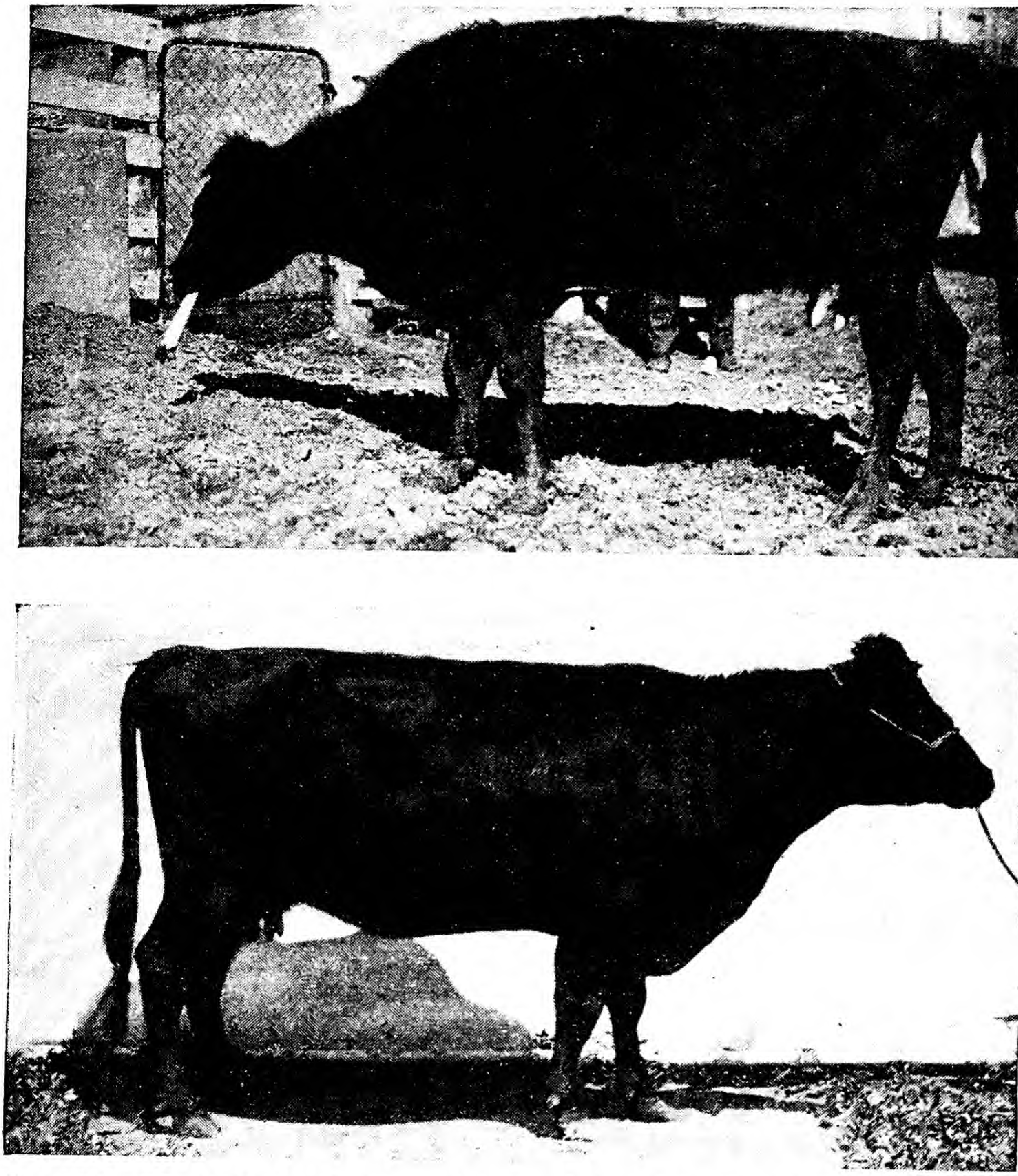

Fig. 104. Effect of phosphorus deficiency. (*Upper*) Cow suffering from phosphorus deficiency, showing unthrifty condition and bone chewing depraved appetite. (*Lower*) Same cow after phosphorus has been added to the ration.

In all cases the appetite for food declines, resulting in emaciation. The affected animal becomes listless and moves about but little. In rickety animals the bone structure becomes less dense, resulting in weak and brittle bones that fracture easily. (Fig. 105.) In phosphorus deficiency the inorganic phosphorus content of the blood is greatly lowered. The normal phosphorus content in blood is about 5 milligrams per 100 cc. In severe phosphorus deficiency, the phosphorus content of the blood may be as low as 1 to 2 milligrams per 100 cc. of blood.

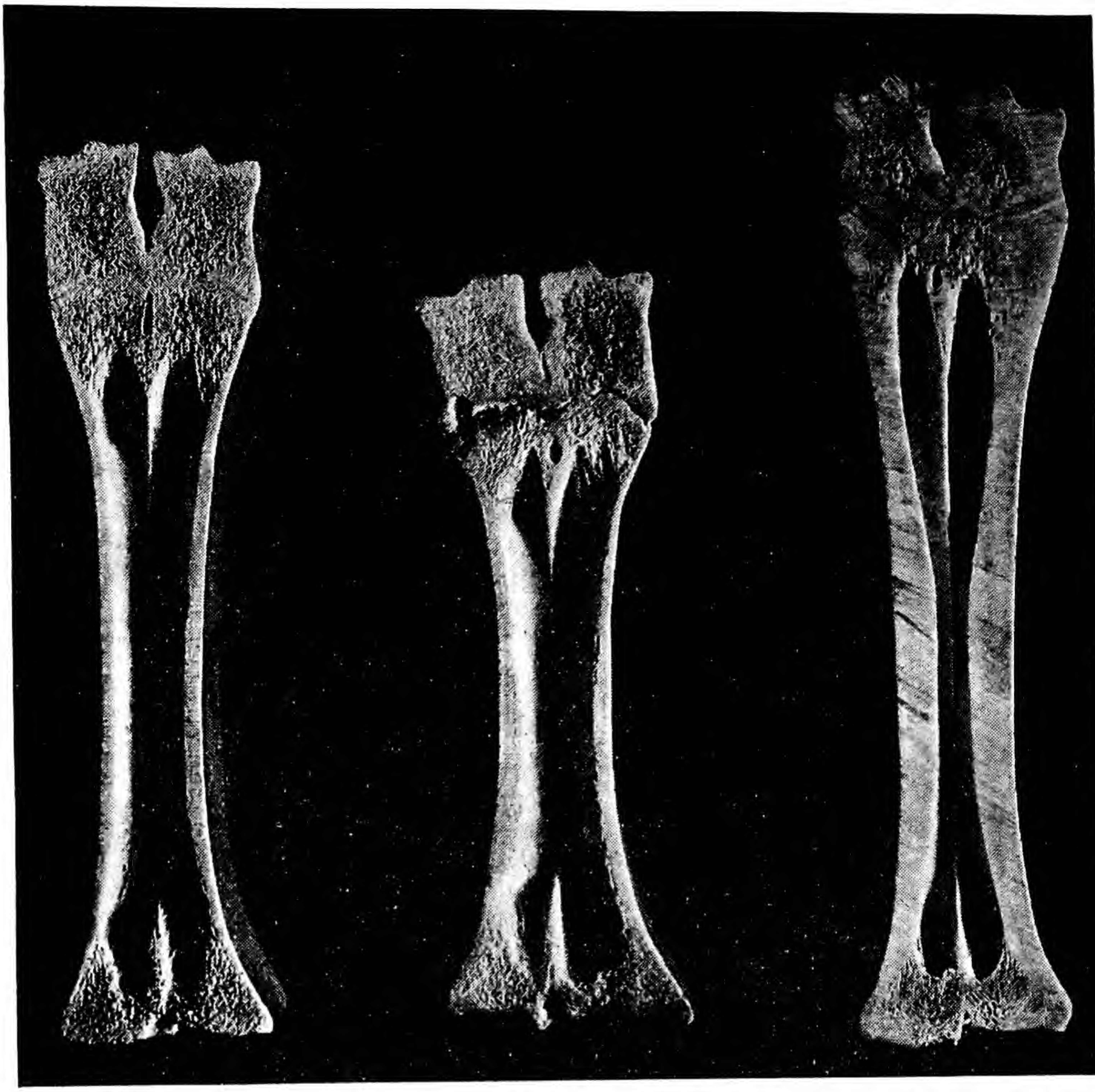

Fig. 105. Effect upon the bone of insufficient phosphorus and vitamin D in the ration: (*left*) the effect of continued phosphorus deficiency; (*center*) effect of insufficient vitamin D; (*right*) good bone. Note the thin walls and porosity of the bones from phosphorus and vitamin D deficient diets.

If the deficiency is corrected in the early stages, recovery may be effected. If the disease is permitted to develop to advanced stages before remedial measures are undertaken, the damage done may be irreparable. Secondary infection may set in in the joints of rickety animals, causing destruction of the bone tissue.[1]

For older animals, calcium, phosphorus, and vitamin D deficiencies[2] produce somewhat different effects, as the bone is through growing. Calcium and phosphorus is withdrawn, leaving the bone in a porous condition known as osteoporosis. The most common mineral deficiency is that of phosphorus,[3] the symptoms of which are as follows.

[1] Bechdel, Hallman, Huffman, and Duncan. Mich. Agr. Expt. Sta. Tech. Bul. 150.
[2] Wallis. Jour. Dairy Sci. 20:434. 1937.
[3] Eckles, Gullickson, and Palmer. *Op. cit.*

1. Loss of appetite
2. Stiffness with sore joints
3. Arched or humped back when walking
4. Development of depraved appetite: animals chew wood, bones, etc.
5. Decrease in the inorganic phosphorus content of the blood
6. Listlessness
7. Bones become fragile and fracture easily
8. Animals become emaciated
9. Milk production decreases rapidly
10. Reproduction is interfered with

In localities where phosphorus deficiency is severe, cows frequently milk for but a short time and produce calves every second year. There is evidence that when cows suffer from phosphorus deficiency, the feeds are used less efficiently; this is probably due to some derangement of the metabolic mechanism.

Huffman[1] and associates recommend 10 grams of phosphorus for maintenance per 1,000 pounds live weight and 0.75 gram for each pound of milk produced. Gullickson[2] recommends 10 grams phosphorus per 1,000 pounds of live weight and 0.7 gram per pound of milk. Gullickson also recommends a minimum of 20 grams of calcium for maintenance per 1,000 pounds and 0.85 gram for each pound of milk.

As to whether there are any extended deficiencies in calcium among dairy cattle is still not proved. Animals on a ration consisting of concentrates only frequently suffer from ricket-like symptoms, but this may be due to a lack of sufficient vitamin D.

Calcium and phosphorus should be added to the ration whenever such a deficiency occurs. There are a number of ways in which this may be done. If the soil is deficient in its phosphorus content, a phosphorus fertilizer should be applied; this not only increases the phosphorus content of the feed but increases the yield of plants grown. The phosphorus content of the ration may be brought up to the required level by including liberal amounts of high phosphorus concentrates, such as cottonseed meal, bran, and linseed oil meal. The calcium of the ration will be adequate if the roughage is a legume. In the event that neither of these methods is feasible, these elements may be furnished in bone meal, which contains calcium and phosphorus in the most desired ratio. The bone meal for livestock feeding purposes is steamed and is usually labeled "for livestock feeding." Such bone meal usually contains 30 to 35 per cent calcium and about 15 per cent phosphorus, and the protein content is usually not over 7.5 per cent.

Bone meal may be fed either by mixing it in with the concentrate or offered *ad libitum*. Cows will usually eat what they need and no more if given free access to bone meal. A little salt may be mixed with the bone

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[1] Huffman, Duncan, Robinson, and Lamb. *Op. cit.*
[2] Gullickson and Fitch. Minn. Agr. Expt. Sta. Bul. 218.

meal to improve the palatability. Fertilizer bone meal should never be used for feeding cattle as it contains foul odors that are objectionable to them.

While bone meal is a satisfactory source of both calcium and phosphorus, a number of other materials may be used. Spent bone black is just as good a source of these two elements, containing about 65 per cent as much of each as is found in bone meal. If it can be purchased for not more than 65 per cent of the price of bone meal, it may replace bone meal.

Various rock phosphates may be used, but care should be taken to insure their being low in fluorine content. The average rock phosphate contains enough fluorine to cause deterioration of the teeth and bone.

Complex mineral mixtures are usually poor sources of phosphorus, the most essential mineral element that they contain. Most of these mineral mixtures contain less than one-third as much phosphorus as bone meal does. In addition to being relatively poor sources of phosphorus, they contain a number of ingredients few of which will be of any value to the animals.

Iodine. When iodine is deficient in the ration, the deficiency is manifested by goiter in the calves at birth. This condition is quite common in large areas in the United States and Canada, being particularly prevalent in the Great Lakes region. Goiter in calves may be prevented by feeding a small amount of iodine to cows during the latter half of pregnancy. A better way is to feed iodized salt to the entire herd. Iodized salt containing 0.02 per cent potassium iodide is available on the market at a slight increase in cost over ordinary salt. Some claim that iodine in excess of the amounts needed to prevent goiter is beneficial; however, this claim is at present lacking proof. The feeding of 15 grains of potassium iodide weekly improved the condition of the coat, but other beneficial effects are not known.

Copper and iron. Copper and iron have been known to be necessary for the formation of hemoglobin, but until recently no known deficiency of these elements had been brought to the attention of students of this phase of cattle's diet. In Florida forage grown in some areas is so deficient in these elements as to produce a condition known as "saltsick," which frequently is severe enough to cause death.[1] The affected animals become emaciated, lose their appetites, and exhibit increased respiration. The hemoglobin content of the blood drops to a very low level, and death may ensue because of anemia. The affected animals make rapid recovery when fed a mixture of 100 parts salt, 25 parts iron oxide, and 1 part copper sulphate. In some areas only copper is found to be deficient, while in others iron or both iron and copper are inadequate.

Milk is low in its iron and copper content, and calves continued on milk as the sole diet suffer from anemia. The addition of iron and copper to such a diet prevents the onset of anemia, but milk so supplemented is still inadequate as the only diet for calves.

[1] Becker, Neal, and Sheely. Fla. Agr. Expt. Sta. Bul. 231.

Cobalt. Within the past year cobalt has been shown to be an essential mineral for cattle. Reports from New Zealand, Australia, Michigan, and Florida show that in some cobalt deficient areas, cattle respond to an addition of cobalt to the ration. Cobalt deficient animals show a long rough coat of hair, scaliness of the skin, loss of appetite, and atrophy of the muscles. In addition, the development of sexual characteristics is delayed and the affected animals are listless. The hemoglobin to red blood cell ratio is reduced. Recovery is effected by the addition of 5.0 to 10.0 mgs. of cobalt per day to the diet.

The other minerals. There is no report of cattle suffering from a deficiency of manganese or of sulphur. Calves on a milk diet alone may suffer from insufficient magnesium. Sulphur cannot be used by the animal in the inorganic form; it must be supplied in the organic form in cystine or methionine.

The vitamins. There are five vitamins or groups of vitamins generally recognized; some of them are of importance in the feeding of dairy cattle. The vitamins are A, B complex, C, D, and E.

Vitamin A. Vitamin A is a fat soluble substance synthesized in the animal body from yellow plant pigments, of which carotene is the chief one. Vitamin A is needed by the animal for growth, reproduction, milk production, and to give resistance to infection of epithelial surfaces of the eyes and respiratory tract. Lack of vitamin A also affects the nervous system and the rods and cones of the eye.

Cattle suffering from a lack of vitamin A manifest the following symptoms: cessation of growth, loss of appetite, nasal discharge due to infection of mucous membranes, infection of the eyes, blindness in severe cases, muscular inco-ordination, and emaciation. Pregnant cows on vitamin A deficient rations may abort, produce dead or blind calves at normal time, or calves so weak at birth they do not survive.[1] In other species sterility accompanies vitamin A deficiency. (Fig. 106.)

Vitamin A is supplied in the normal ration through the carotene content of the feed, one molecule of which produces two molecules of vitamin A. Carotene is associated with the green coloring matter of plants; in general, feeds handled to preserve the green color will also preserve the carotene. Carotene is very susceptible to destruction through oxidation. Roughage that remains standing until it is mature and bleached, that becomes bleached in the process of curing, or that heats in the mow or silo will lose most of its carotene. In order to supply adequate amounts of carotene, it is important that roughages be cured and stored in such a way as to preserve the carotene. Hays should be cut when still immature and cured without being rained upon or exposed to excessive sunlight.

While the artificial drying of hays is very expensive, it insures maximum preservation of the carotene. Acid treatment of legumes and grasses when ensiled reduces fermentation and preserves the carotene. Recent work indicates that the addition of molasses to ensiled material has the same effect.

[1] Meigs and Converse. Jour. Dairy Sci. 16:317. 1933.

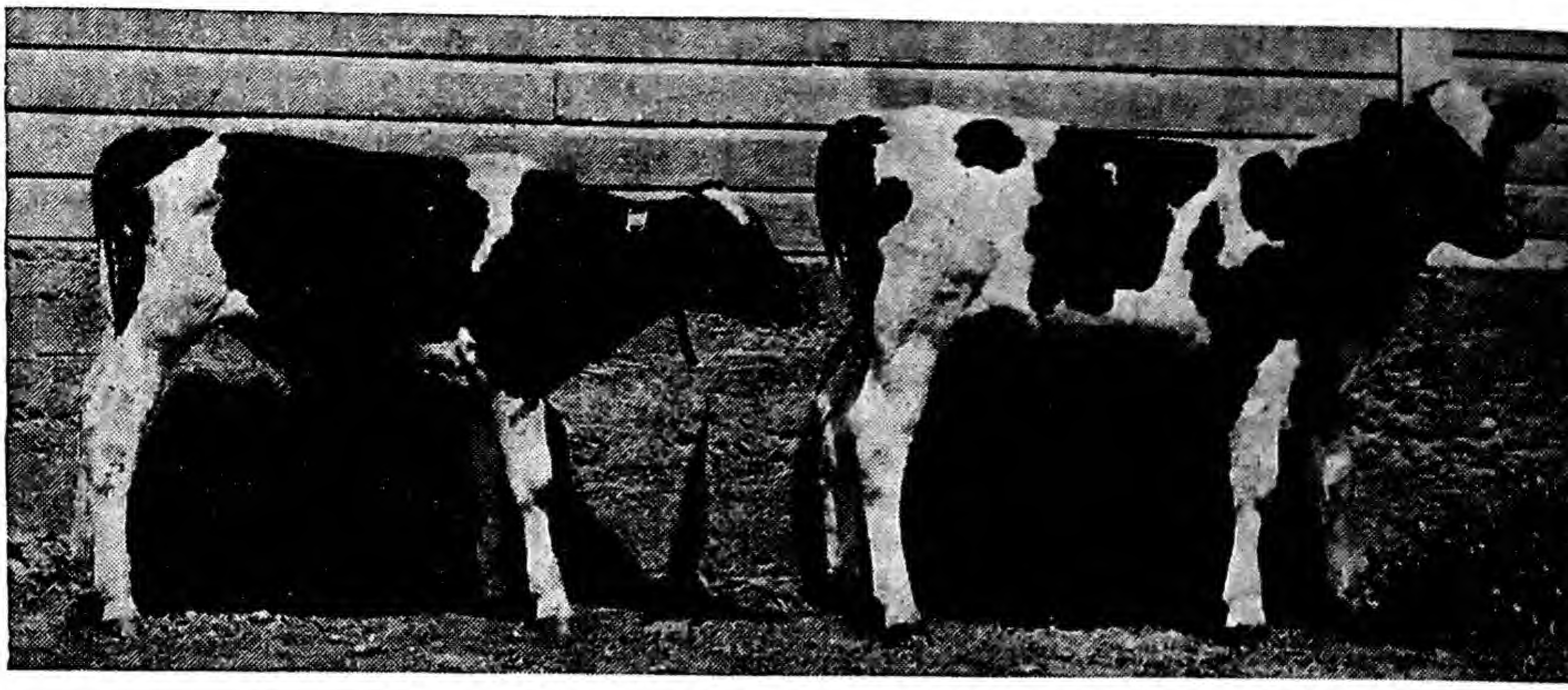

Fig 106. Showing the effects of vitamin A deficiency. Twin heifers, the one on the left having had insufficient vitamin A. Note the smaller size and general unthrifty appearance of the vitamin A deficient calf.

Cod-liver oil, an exceedingly rich source of vitamin A, may be fed young stock and dry cows when the ration is known to be deficient in vitamin A. For milking cows, however, cod-liver oil depresses the fat content of the milk and should not be used.

In addition to promoting normal growth and physiological functions of dairy cattle, vitamin A assumes an important role in that the amount present in milk is directly proportional to the amount of carotene in the feed.[1] Green grass is the highest of dairy cattle feeds in carotene content, and the milk produced from green pasture is the highest in vitamin A. As one of the chief sources of vitamin A in the human diet is from butter and milk, the production of milk with high vitamin A content may become of increasing importance.

While there is no apparent difference between individual cows and breeds in the total vitamin A potency (vitamin A and carotene) of the milk produced from a given feed, there is a marked difference in the proportion of vitamin A and carotene secreted in the milk. In general, Guernseys and Jerseys convert less of the carotene into vitamin A and secrete more carotene in the milk than do Holsteins and Ayrshires.

Vitamin B complex. At first vitamin B was thought to be a single substance which prevented beri-beri and polyneuritis. Recent work has shown that several vitamins are included, and it is now generally referred to as the vitamin B complex. There is no evidence that vitamin B in any of its different forms is needed in the ration for the normal nutrition of cattle. Cattle undoubtedly need vitamin B but are capable of synthesizing it in the rumen.[2] Calves do not synthesize this vitamin complex.

Vitamin C. Vitamin C or ascorbic acid, like the vitamin B complex, is not needed in the ration of cattle for normal nutrition except for young calves. There is also some evidence that some cases of sterility in both bulls and cows may be due to a low blood content of ascorbic acid. These

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[1] Krauss. Ohio Agr. Expt. Sta. Bul. 470.
[2] Bechdel, Honeywell, Dutcher, and Knutsen. Jour. Biol. Chem. 80:231. 1928.

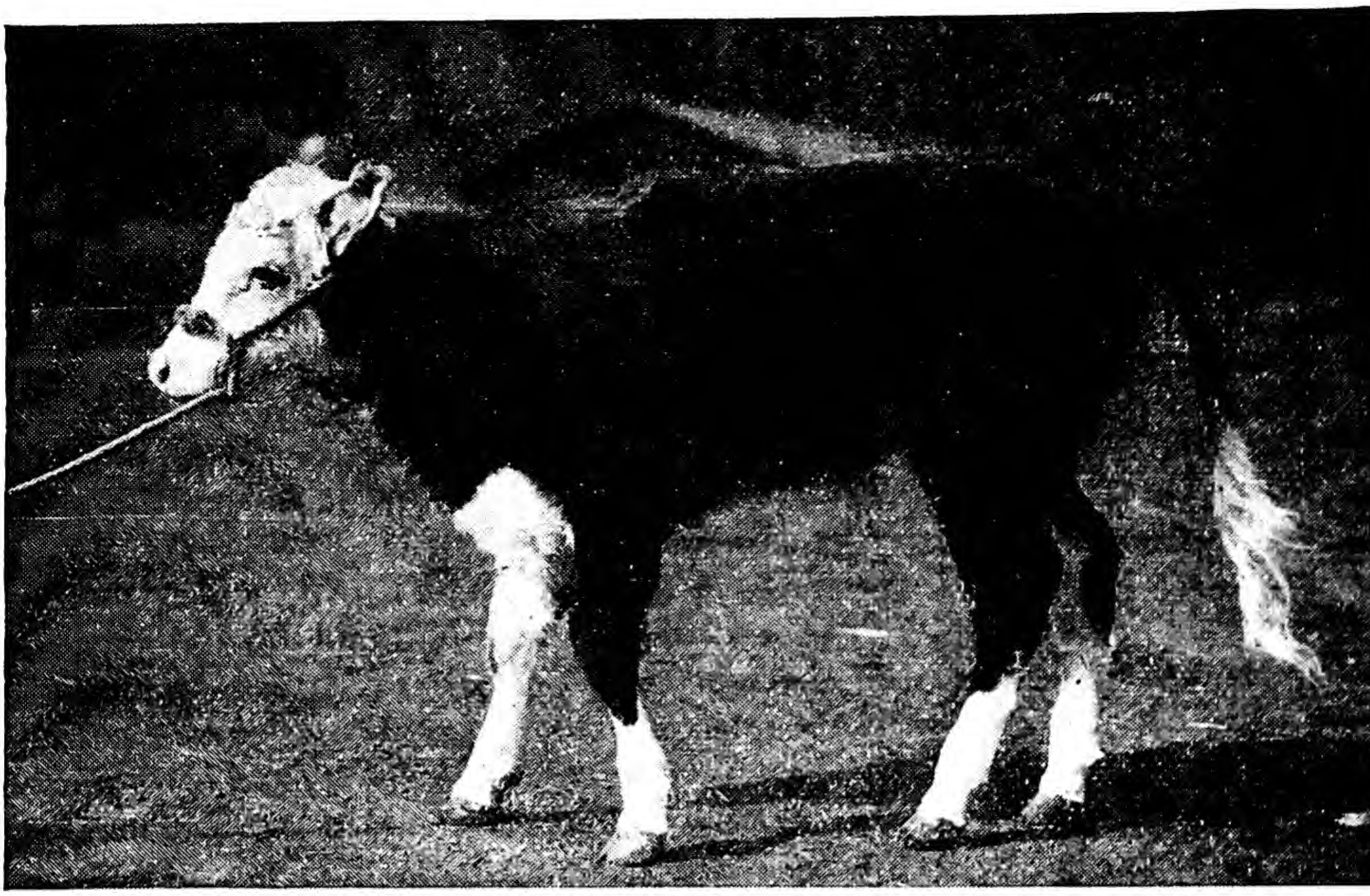


Fig. 107. Effect of vitamin D deficiency. This calf, offered unlimited amounts of grain, did not consume enough hay or adequate vitamin D intake. Note its swollen joints, bent limbs, characteristic pose, and unthrifty condition.

cases respond to subcutaneous administration of the vitamin. All green feeds are rich sources of ascorbic acid, which is of no avail to the bovine with a functional rumen because the vitamin is destroyed therein. For young calves the oral administration of ascorbic acid is effective. Recent work has shown that there is no relation between the amount of this vitamin in the diet and its level in the milk.

Vitamin D.[1] Vitamin D is absolutely essential for the normal functioning of cattle. Lack of vitamin D produces rickets in the growing animal and osteoporosis in the mature animal, both of which have already been described. Adequate vitamin D in the ration is also of importance in the production of milk as the vitamin D content of the milk is proportional to the vitamin D content of the feed the cow gets.[2] (Fig. 107.)

Vitamin D may be secured either in the feed or by exposure to direct sunlight. Growing plants are practically devoid of vitamin D. Cows on pasture only, secure all of the vitamin D from exposure to the sun. During the winter when cows are confined in barns, and when the sun's rays are relatively low in ultraviolet light rays (which produce vitamin D in the body), cattle are entirely dependent upon the feed for vitamin D.

Grains contain very little vitamin D, and therefore the chief food source is in the roughage. Vitamin D is produced in the forage by exposure to sunlight during the curing process. Artificially dried rays and silages are poor sources of this vitamin. There is no evidence that cattle fed field-

[1] Huffman and Associates. Jour. Dairy Sci. 18:511, 605; 19:291, 359.
[2] Olson and Wallis. S. Dak. Agr. Expt. Sta. Bul. 296.

cured hays suffer from vitamin D deficiency, and there is apparently enough vitamin D in such roughage for the requirements of the animal. Calves securing milk with low vitamin D, and those fed grain and no roughage, may develop rickets. It has been observed that calves allowed access to unlimited amounts of concentrate will develop rickets, as under such a condition they will eat little or no hay.

In some places special markets have been developed for "vitamin D milk." Such milk contains a definite minimum amount of vitamin D, produced by feeding irradiated yeast to the milking cows at the rate of 3.4 ounces yeast for 20 pounds of milk; the ration of yeast to milk is decreased with increasing production, until when a cow produces 50 pounds of milk, only 5.6 ounces of yeast is fed.

Vitamin E. While vitamin E is necessary for reproduction in some species, it has been shown by extensive experiments at the University of Minnesota that this vitamin is not needed in the diet of either cows or bulls for normal reproduction. Four generations of cattle have been raised on a vitamin E-free diet with better than normal fertility records. A number of the animals on the experiments have died suddenly from heart failure. Deaths occur usually following some such strain as exercise or following calving. By electrocardiograph tracings the heart defect can be picked up in otherwise normal appearing animals.

Vitamin E is found in the germ of seeds, in green plants, and in the leaves of well preserved hay. It is difficult to prepare a ration for cows that does not contain enough of this vitamin.

Feeding standards. The so-called feeding standards deal only with the protein and energy requirements of the animal. The various feeding standards prescribe the needs of the animal in nutrients. The first feeding standard was proposed in 1859 following the beginning of interest in agricultural chemistry and has been modified at frequent intervals since that time.

In 1859 Groven proposed the first feeding standard, basing the requirements upon total crude protein carbohydrates and fat. In 1864 Wolff offered an improvement by producing a feeding standard based upon the digestible crude protein, carbohydrate, and fat. In 1896 Lehmann modified the Wolff standard to bring it into accord with accumulating knowledge. This standard, known as the Wolff-Lehmann standard, was widely used. Haecker made further improvement by determining the nutrient needs for milks of varying richness; this standard, which up to that time had been ignored, is still in wide use for dairy cattle. Savage made further refinements. But the most comprehensive work is that of Morrison; over a period of years, he has gathered all the new information on feed requirements for farm animals and incorporated the data into the Morrison feeding standards. The latest and most comprehensive Morrison standard was published in 1936. In the main, each successive revision of the feeding standards has been characterized by lower protein requirements.

While most of the work done on feed requirements has been on the

basis of digestible nutrients, others have worked on the energy requirements. The work of Kellner in Germany and of Armsby in this country is outstanding. Kellner proposed feeding standards stating the requirements in digestible true protein and starch values. Armsby extended and refined Kellner's work and published feeding standards based upon digestible true protein and therms net energy. These standards have not been popular, most people preferring to use the digestible nutrient standards.

Haecker's feeding standard. The most comprehensive study of the nutrient requirements for milk production was made by Professor Haecker at the University of Minnesota. This was published as the Haecker feeding standard, which has been used extensively in the United States. In formulating his standard Haecker added about 10 per cent to what he actually found was required. Recently Dr. Gullickson [1] has reworked Haecker's data and revised the Haecker feeding standard to the actual requirement as found by Haecker. The revised Haecker standard agrees very closely with the latest revision of the Morrison standard. The revised Haecker feeding standard is given in Table I of the Appendix.

The original Haecker standard had the requirements expressed in digestible crude protein, digestible carbohydrate, and digestible crude fat. In the revised standard the requirements are expressed in terms of digestible crude protein and total digestible nutrients.

Use of the feeding standard. The use of the feeding standard serves to check the adequacy of the ration from the standpoint of the digestible nutrient supplied. Every now and then the feeder of dairy cattle should check up on the requirements of the cow and ascertain how much of the various nutrients is supplied in the ration. Only by so doing can he be both appraised of and put in a position to correct a possible deficiency in the ration. As the requirements of any milking animal are determined from maintenance and milk produced, one must first ascertain what the requirements are for maintenance, and what the requirements are for the amount and quality of milk produced. Assuming that the cow weighs 1,250 pounds and produces 40 pounds of milk containing 4 per cent fat, upon referring to Tables I and II in the Appendix, the requirements in digestible crude protein and total digestible nutrients are found to be as follows:

	Digestible Crude Protein	Total Digestible Nutrients
	Pounds	*Pounds*
For maintenance............	.756	8.40
For 40 pounds, 4% milk......	1.848	13.416
Total required............	2.604	21.816

[1] GULLICKSON AND FITCH. FEEDING THE DAIRY HERD. Minn. Agr. Expt. Sta. Bul. 118. 1938.

After finding the requirements, the next step is to ascertain the amount supplied. Assuming that the cow is to be fed 35 pounds of corn silage, 15 pounds of timothy hay, and 10 pounds of a grain mixture consisting of equal parts of oats, bran, corn, and barley, from Table II in the Appendix the nutrients supplied are calculated as follows:

	Amount	Digestible Crude Protein	Total Digestible Nutrients
	Pounds	*Pounds*	*Pounds*
Corn silage	35	.420	5.980
Mixed hay	15	.765	7.395
Oats	2.5	.255	1.738
Bran	2.5	.323	1.690
Corn	2.5	.183	2.038
Barley	2.5	.243	1.928
Total		2.189	20.769
Additional nutrients needed		.415	1.047

It is seen that the ration falls short of supplying the requirements by .415 pounds of digestible protein and 1.047 pounds of total digestible nutrients. The next step is to supply the additional needed nutrients. Referring again to Table II in the Appendix, ground soybeans are found to have about the right proportions of protein to total digestible nutrients to fit the additional needs. Adding 1.25 pounds of ground soybeans, the nutrients supplied are as follows:

	Digestible Protein	Total Digestible Nutrients
	Pounds	*Pounds*
Previously supplied	2.189	20.769
Soybeans, 1.25 pounds	.421	1.154
Total	2.610	21.923
Above requirements	.006	.107

With the addition of the ground soybeans, the requirements are met with but a slight excess and the ration is balanced. If some other high protein feed is cheaper and easier to procure, it may be used even though an excess of protein is furnished, in order to secure the additional total digestible nutrients needed to meet the requirements.

Recommended nutrient allowances for dairy cattle. After a study of published experimental work a committee[1] of the National Research Council has reported, tentatively, in tabular form, recommended levels of

[1] Loosli, Huffman, Petersen and Phillips. Recommended Nutrient Allowances for Dairy Cattle. Nat. Res. Coun. 1945.

the nutrients for which sufficient information is obtainable for the various stages of growth, maintenance, and location. This table is reproduced as follows:

RECOMMENDED NUTRIENT ALLOWANCES FOR DAIRY CATTLE
(Tentative)

Weight of Animal	Expected Gain		Daily Allowance Per Animal [1]					
	Jersey	Holstein	Digestible Protein	Total Digestible Nutrients	Ca	P	Carotene	Vitamin D
Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Gm.*	*Gm.*	*Mg.*	*I.U.*
Growth:								
50	0.5	...	.30	1.0	4	3	[2]	150
100	1.0	0.8	.45	2.0	8	6	6	300
150	1.3	1.4	.60	3.0	12	8	10	450
200	1.4	1.6	.70	4.0	13	9	12	600
400	1.2	1.8	.80	6.5	14	11	25	1200
600	0.8	1.4	.85	8.5	15	12	35	....
800	1.1	1.2	.90	10.0	15	12	45	[3]
1000	...	1.3	.95	11.0	14	12	60	....
1200	...	1.2	1.00	12.0	12	12	70	....
Maintenance [4]								
700			.45	6.0	7	7	40	[3]
1000			.60	8.0	10	10	60	....
1200			.70	9.5	12	12	70	....
1400			.80	11.0	14	14	80	....
Pregnancy (per 1000 lbs.) (Last 6 to 12 weeks)			1.2	14.0	22	17	90	[3]
Lactation (per lb. milk)								
3.0% fat			.040	.28	1	.7	[5]	[5]
4.0% fat			.045	.32	1	.7	..	....
5.0% fat			.050	.37	1	.7	..	....
6.0% fat			.055	.42	1	.7	..	....

[1] Thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, and vitamin K are synthesized by bacteria in the rumen and it appears that adequate amounts of these vitamins are furnished by a combination of rumen synthesis and natural feedstuffs. Manganese, iron, copper, and cobalt are clearly essential but the amounts needed are not known. For growth 0.6 gm. magnesium is needed per 100 pounds body weight.

[2] Calves should receive colostrum the first few days after birth, as a source of vitamin A and othere ssential factors.

[3] While vitamin D is known to be required the data are inadequate to warrant specific figures for older growing animals and for maintenance, reproduction, and lactation.

[4] When calculating the allowances for lactating heifers that are still growing, it is recommended that the figure for *growth* rather than *maintenance* be used.

[5] When adequate amounts of vitamins A and D are fed for normal reproduction, extra amounts will probably not stimulate milk production but will increase the vitamin content of the milk.

Water. Water constitutes from 70 to 80 per cent of the animal body, carries the digested food materials into the body, carries waste products away from the body, helps to control the body temperature through evaporation from the skin, and constitutes more than 87 per cent of milk. An animal can live longer without food than without water. The water requirement of milking cows is the highest of any farm animal. The amount of water required varies according to the size of the cow, the amount of milk produced, the type of feed, and the atmospheric temperature.

The water for maintenance is proportional to the size of the cow, as are the other nutrient requirements. The additional water needed for milk production varies from 3.5 to 5.5 pounds of water for each pound of milk produced. The feed influences water requirement in two ways. If silage, green forage material, or other feeds of high water content are fed the additional water requirement is reduced. If cows are not given salt regularly, the water requirement is increased following the feeding of salt. The atmospheric temperature greatly influences the water requirement. Cows may consume as much as 80 per cent more water on warm days than on cold days.

Whether cows are on pasture or in the barn, free access to water at all times produces the best results. The Iowa Station reports that when cows have free access to water, they drink, on an average, 10 times during 24 hours. Free access to water in drinking cups increased milk production 2.8 per cent and butterfat production 2.1 per cent as compared to watering twice daily, according to United States Department of Agriculture reports. The Iowa Station reported 3.5 per cent increases for milk and 10.7 per cent for butterfat for similar experiments. A number of other experiments prove conclusively that increased milk production over that obtained when the cows are watered twice daily, results when cows have constant access to water, and that still further increases result over watering once daily when dry feeds are fed. When large quantities of succulent feeds are fed twice or more daily, the advantages of free access to water becomes less.

Suitability of the ration. For a ration to be suitable, a number of conditions must be met:

1. It must furnish all of the nutrient requirements in adequate amounts.
2. It must be palatable so that the cows will eat enough.
3. It must have the proper bulk.
4. Succulence may be desired.
5. It must not be too laxative or constipating.
6. It must not be injurious.
7. It must not be detrimental to the milk.
8. It must not be too expensive.

Balanced ration: enough nutrients. The first essential in the formulation of an adequate ration is that it contain adequate amounts of all the dietary requirements. The feeding standard serves as a valuable tool in ascertaining whether or not the ration is adequate in its digestible protein and total digestible nutrient content. Care should be taken to furnish the minimum requirements of both protein and total digestible nutrients. If either one of these values is below the required level, results will be limited to the level of the lower constituent. Except for the increase in costs due to the usual high cost of protein, there is no harm in furnishing larger amounts of digestible protein than are required as the excess protein is used for energy purposes. The old idea that an excess of protein is harmful to the animal is not borne out by modern knowledge. The balancing of the

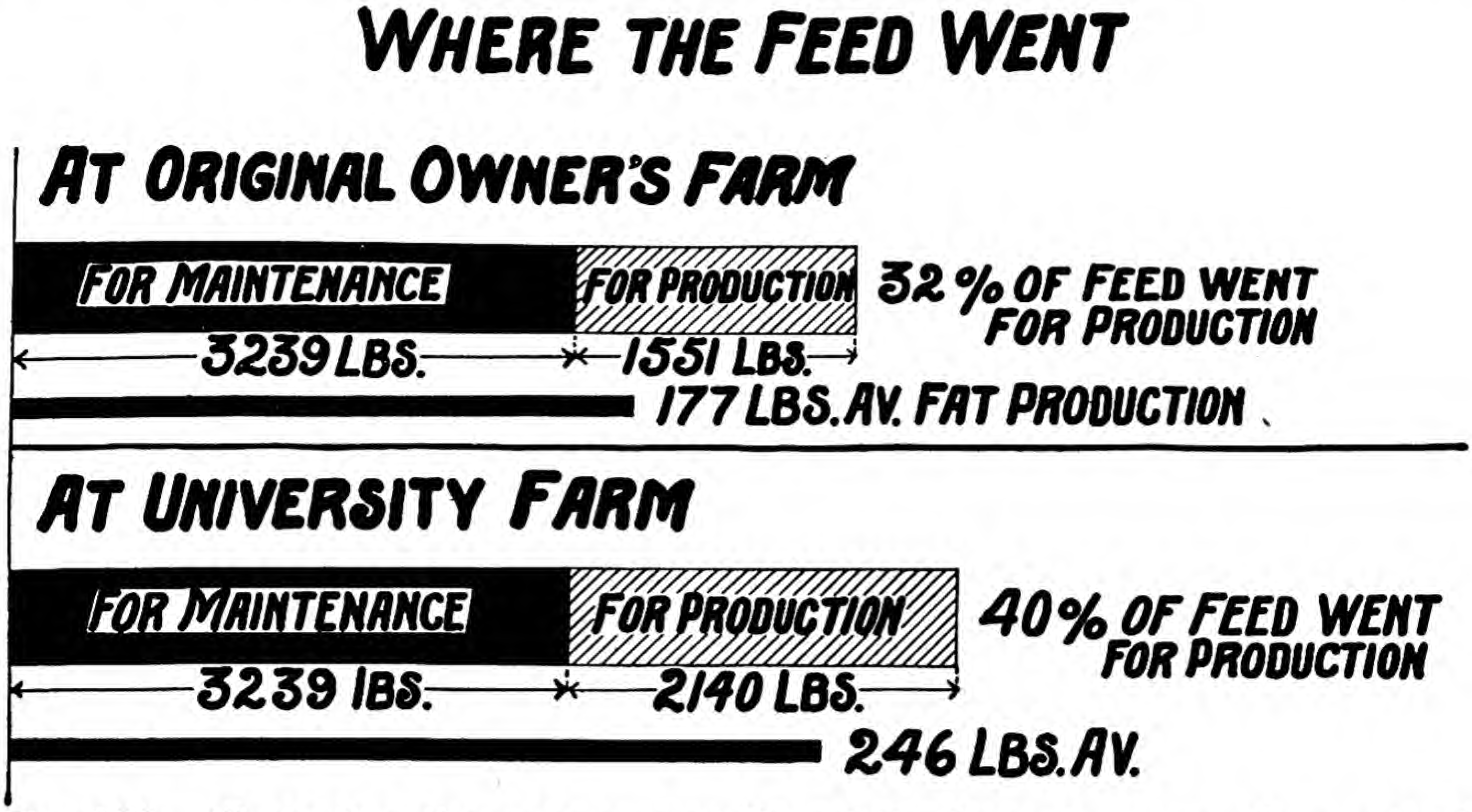


Fig. 108. Illustrating the economy of liberal feeding. A group of cows fed on limited rations were purchaed by the University of Minnesota and fed liberal rations with the above results. The average actual fat production increased from 177 pounds to 246 pounds.

ration is essential only in reducing costs when high protein feeds are purchased and when such feeds are higher priced than lower protein feeds.

In order to insure adequate supply of the minerals, more judgment is required on the part of the feeder. Except for common salt, which must be furnished everywhere, the need for mineral supplements varies with the locality and the type of feeds fed. In phosphorus deficient areas and where roughage only is fed, a phosphorus supplement should be used. The guide as to the need would be the amounts the cow will consume *ad libitum*. Additional calcium is probably needed where the ration is largely a concentrate or where the roughage is the low calcium type (such as timothy) grown on acid soil. Calcium may then be added either in bone meal or in marl, ground limestone, or slaked lime. Iodine, as has been previously indicated, should be furnished in iodized salt in areas known to be deficient in iodine. The other essential minerals are naturally deficient in very limited areas. In such areas the proper supplement should be furnished.

An adequate supply of the various vitamins is more difficult to furnish because the absolute need by the animal is not known and it is difficult to ascertain the amounts of the various vitamins in the feed. When well cured roughage is fed, there is no evidence that cows suffer from vitamin deficiency. When badly bleached or partly spoiled roughage is fed, it is probably well to add some cod-liver oil to the ration, particularly if symptoms appear that might be due to lack of vitamins. All young growing cattle should have a good quality of field cured hay to insure adequate vitamin D.

Palatability. Whether a cow will eat enough of a ration to secure the required nutrients is, to a large extent, dependent upon the palatability of the ration. The question of palatability is particularly important with high producing cows when roughage is to supply the major portion of the ration. There are marked differences in the quantities of different feeds that cows will eat. Malt sprouts, rye, and screenings with a large amount of mustard seed, while good from a nutritive standpoint, are unpalatable, and many cows will not eat mixtures containing very much of these feeds. When such feeds must be used they should be mixed in with other more palatable feeds. Molasses serves a very useful purpose in increasing the palatability of otherwise unpalatable feeds.

From the standpoint of palatability, roughages vary more than concentrates. The factors affecting the palatability of roughages are the variety of roughage, stage of maturity when cut, how cured, the storage, and probably the soil upon which grown. Of these the stage of maturity when cut and the curing are the most important factors. All hays, whether of the legume or the grass variety, become more unpalatable with advance in maturity. Ripe hays and grasses are very unpalatable; cattle frequently refuse to eat as much as one and one-half pounds per 100 pounds live weight. Curing the hay affects palatability to about the same extent that tha maturity of a plant does. Hays that have been rained upon and bleached in curing lose the factors that make for palatability. Alfalfa hay cut in the early bud stage and cured to a pea green color is so palatable that cows will eat up to three or four pounds per 100 pounds of live weight.

Bulk. Bulkiness of feed, which is due to the fiber content, is of importance for two reasons: if the ration is too bulky, the animal does not possess capacity to handle enough to secure the necessary nutrients; and if it lacks bulk, digestive disturbances may be produced. Dairy cows have been fed on nothing but concentrates and have appeared to be normal when calcium and vitamins A and D were supplied; this proves that large quantities of crude fiber are not essential for cattle. However, when concentrates are fed in large quantities, unless they are "lighted" with some more fibrous feeds, such as bran or oats, indigestion frequently results, with the cow going "off feed."

The reason for feeding concentrates to dairy cattle is to increase the nutrient intake. The cow's capacity for feed is limited and the limitation is based on dry matter; one pound of grain replaces one pound of hay. By increasing the concentrate allowance, the amount of hay consumed is decreased; but as concentrates on the average contain 50 per cent more total digestible nutrients, there is an increase in the nutrient intake.

Succulence. It is usually assumed that some succulent feed in the ration is essential for the best results. That succulent feeds do improve the average ration is not to be denied; but when a good grade of legume hay is fed, there is a question of the advisability of adding succulence if it adds to the cost of the ration. Recent work has shown that when cows were fed a good grade of alfalfa hay, they produced equally well whether or not they secured corn silage.

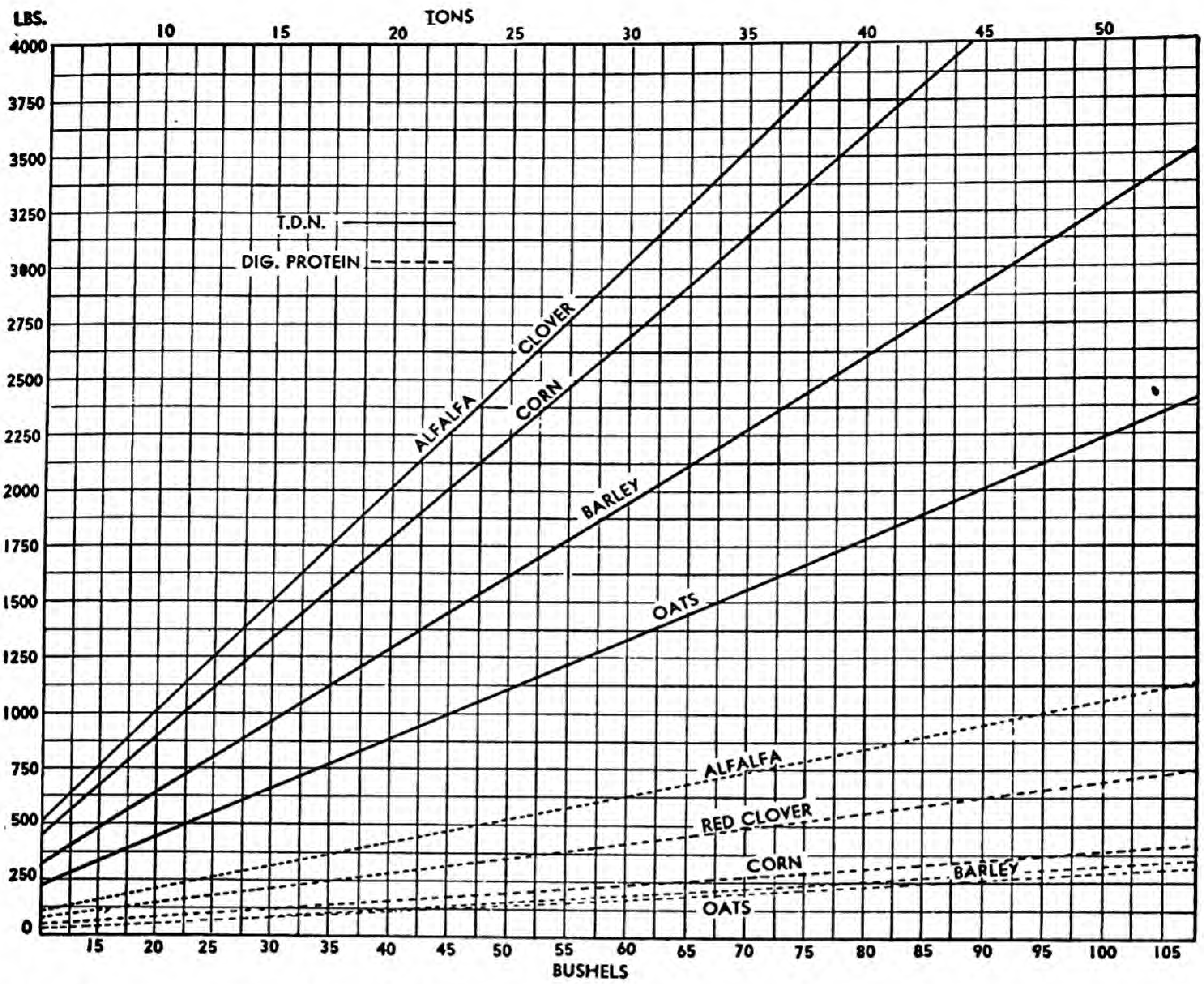


Fig. 109. Showing the total digestible nutrients and digestible crude protein for alfalfa, clover, corn, barley, and oats. It requires approximately 90 bushels of oats to equal the total digestible nutrient content of two tons of alfalfa hay.

The good results experienced when cows are on luxuriant green grass, which has been attributed to succulence, is due to the superior nutrient qualities of the immature plants. Equally good results may be obtained by feeding the grass in dried form.

Effect of feeds upon milk. It has previously been noted that the flavor of milk and cream is dependent upon the feeds, and that many feeds possess compounds which pass into the milk to produce off flavors. It is, therefore, important that feeds be selected which will not produce undesirable flavors in the milk and cream.

Effect of poisonous feeds upon the system. A ration should be slightly laxative and, of course, nonpoisonous. Some rations are constipating, leading to resorption of undesirable material from the digestive tract and systemic poisoning. Mature hays and straws are usually constipating. This effect may be corrected by feeding silage and bran, which are laxative. Occasionally some feeds are too laxative. The last cutting of alfalfa, if frosted, may prove to be scouring. When this is discovered, the amounts of the offending feed should be reduced until the trouble is corrected.

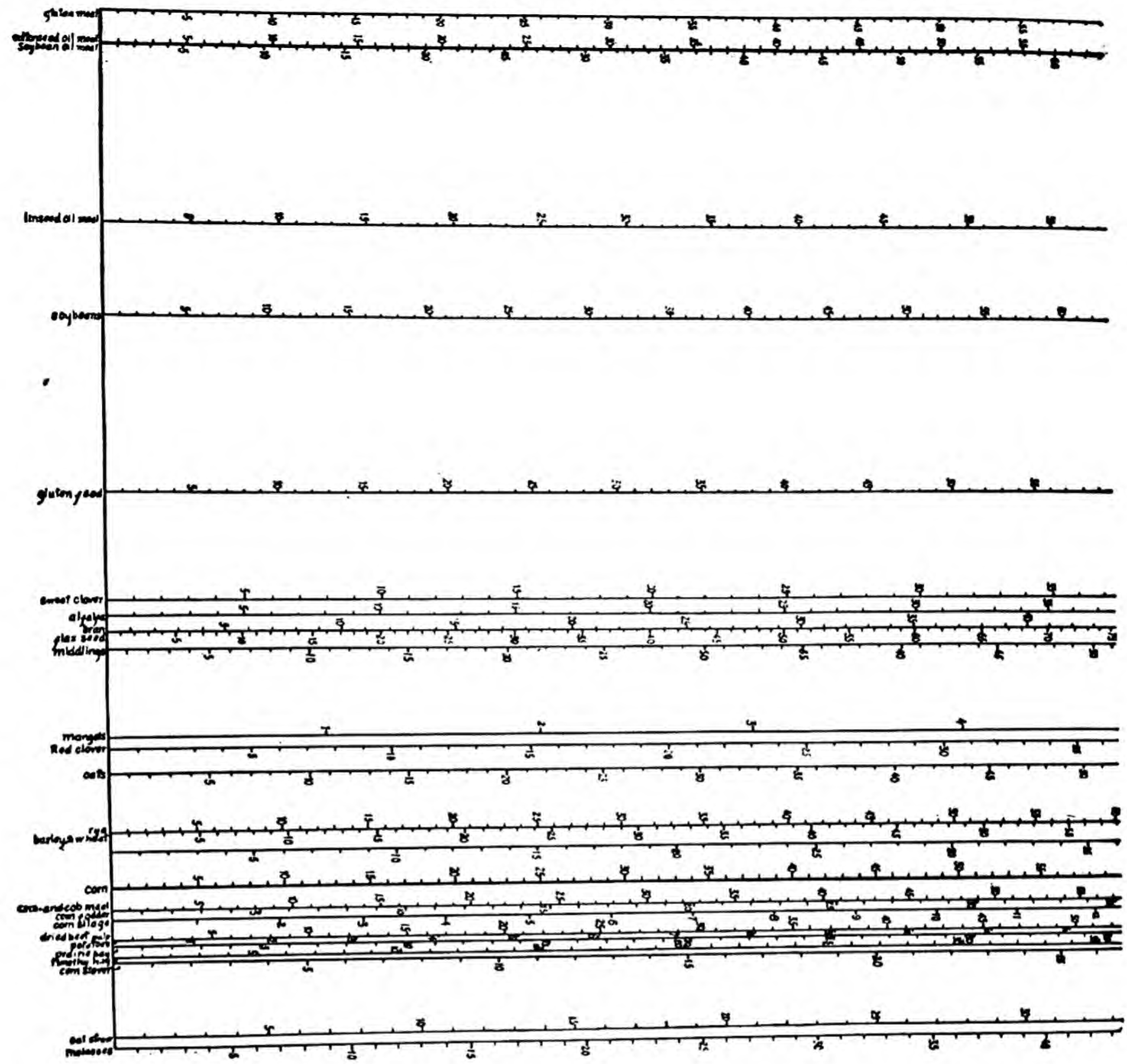
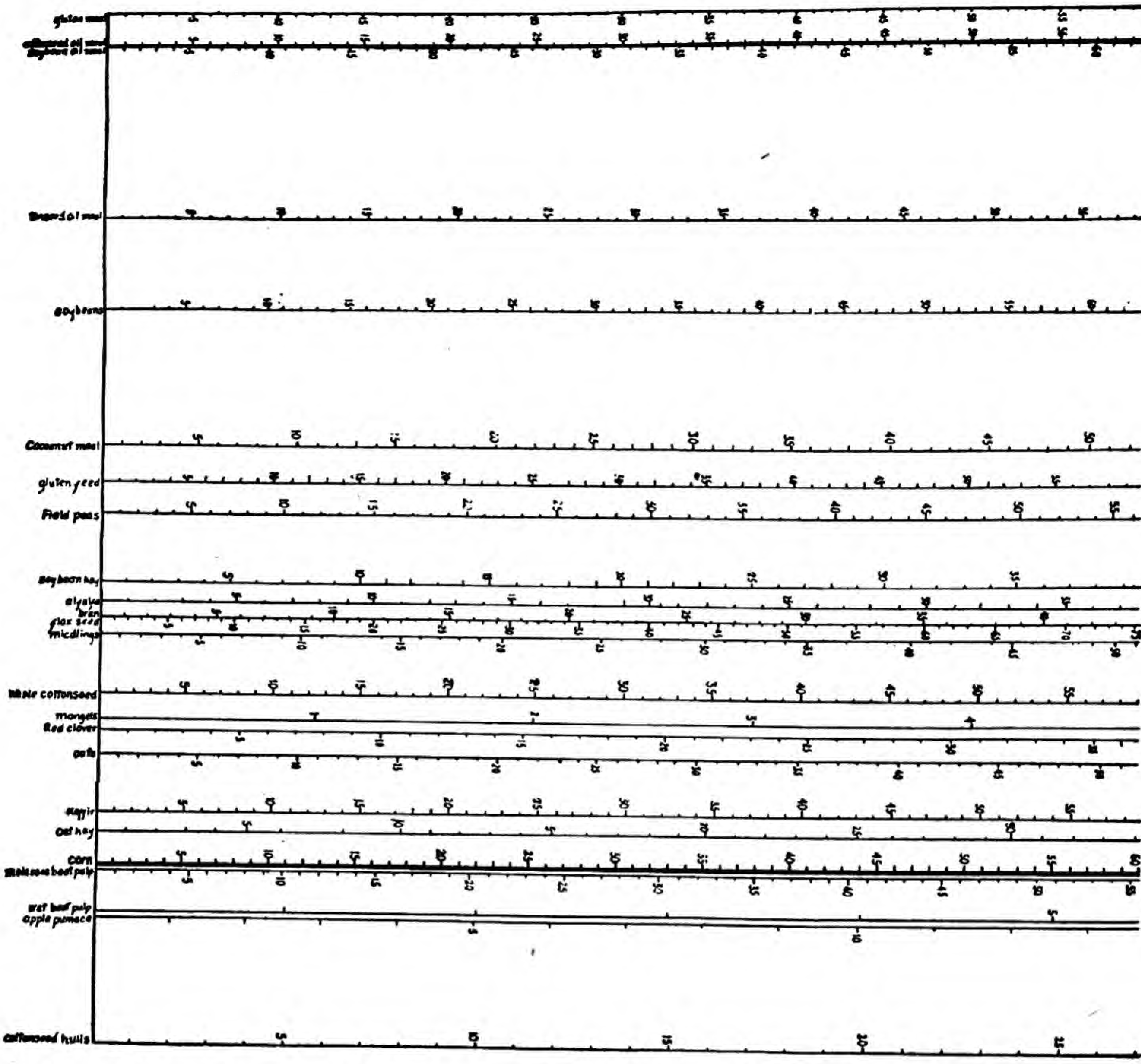


Fig. 110. Graph for determining the value of feeds upon the basis of the and cottonseed meal the value of any feed is indicated at the point of inter-

The number of poisonous plants encountered in the feeding of cattle is greater than is generally acknowledged, and many cases of illness or death may be accounted for through forage poison. While horses and sheep may be poisoned from spoiled or moldy feed, cattle are not susceptible to poisons from this source. Stagnant water, however, may prove poisonous to cattle, as may the rare contamination of botulinus organism. Smuts and scabs are not known to be harmful to cattle. Sweet clover hay or silage, however, frequently prove toxic to cattle when the hay or silage is not properly cured or preserved. Sweet clover poisoning manifests itself by the blood losing its ability to clot; affected animals bleed to death from slight wounds. Ergot, which is frequently found in rye, causes a decline in milk yield, and in severe cases may cause the loss of ear tips, hoofs, and the switch of the tail. The castor bean and castor bean meal are deadly poisons, and small contamination in the feed may prove disastrous.

Selenium is a powerful poison. Many plants grown on soils high in



values of corn and cottonseed meal. By placing a ruler on the values of corn section on the scale for that feed.

selenium content are poisonous to all livestock. Fluorine, as has previously been mentioned, is a poison. Animals fed acid phosphate may suffer from this poison; in some places the fluorine content of water is sufficiently high to be poisonous. Lead, coming from contamination of the feed, from lead sprays, or from lead paints on barns, fence, stalls, or stanchions, has frequently produced illness and death of cattle. A portion of the lead ingested will pass into the milk. Nails, wire, or other sharp metal objects, while not poisonous, are frequently swallowed with the feed and may puncture the stomach wall to enter the heart, lungs, or liver and be the cause of death.

A large group of plants are cynogenic; that is, they produce hydrocyanic or prussic acid under certain conditions. This is highly poisonous to livestock and produces death in a few minutes. Sudan grass, flax, sorghum, Johnson grass, cherry leaves, plum leaves, chokecherry leaves, and a number of other plants possess this compound. The hydrocyanic

acid is present in a compound which is harmless. The poisonous acid is liberated by an enzyme also present in the plant. The enzyme acts when the plant cells are injured from wilting, frost, and other injuries. Severe drought causes a stunting which increases the hydrocyanic acid content. The losses from pasturing cattle on sorghums have been heavy. Dried or ensiled plants are rarely, if ever, toxic.

A number of other plants that are poisonous are white snakeroot, of which the toxin, tremetol, passes into the milk; larkspurs; loco weed; laurels; death camass; water hemlock; milkweed; cocklebur; bracken-fern; lupines; monkshood; and a number of others.

Cost of the ration. As the production of milk is an economic venture, the cost of the ration is of paramount importance. One is confronted with the problem of cost in both the growing and the purchase of feeds. Due to differences in the productivity of different soils for different crops, the question of the cheapest feeds to grow becomes largely a problem for each manager to decide. Careful attention should be given to growing crops that are adapted to the dairy, and those that will yield the largest amounts of digestible nutrients at the lowest cost per unit should be considered. Many dairymen persist in growing crops that are deemed essential in the ration but that are poor yielders of total digestible nutrients and therefore expensive to grow. Oats are frequently low yielders and are expensive to grow, as is brought out in Figure 109. Corn, either for grain or silage in Northern sections, is another example of unsuited crops which become expensive.

When feeds are to be purchased, a method of evaluation, developed by the author, is available which will indicate the cheapest feed on the basis of its nutrient content. By multiplying the prices of cottonseed meal and corn by the constants set forth under these feeds and opposite the feed in question, and adding the two products, a figure is secured that gives the value of the feed. If the market price is higher than the indicated value, a cheaper substitute should be sought.

Example: If corn is worth $20.00 and cottonseed meal $30.00 per ton, what are oats worth?

The constant for corn is . . . . .786 × 20.00 =	$15.72
The constant for cottonseed meal is . . . . . .109 × 30.00 =	3.27
Oats are worth per ton	$18.99

The constants are arrived at from first determining the value of the feed in question from the price of cottonseed meal and corn. As a rule, the former is the cheapest source of proteins and the latter the cheapest source of total digestible nutrients. (Fig. 82.)

As 100 pounds of 43 per cent protein cottonseed meal contains 37.6 pounds of protein and 42.6 pounds of total digestible nutrients, 57.24 pounds of corn (containing 42.6 pounds of total digestible nutrients and 4.1 pounds of digestible protein) can be subtracted therefrom, leaving 33.5 pounds of digestible protein. The difference in costs of 100 pounds

of cottonseed meal and 57.24 pounds of corn should be charged to the 33.5 pounds of digestible protein to give a value for digestible protein.

The formula for determining the cost for a pound of protein is:

$$\frac{\text{Cost of 100 pounds of cottonseed meal} - .5724\ (\text{Cost of 100 pounds of corn})}{33.5}$$

Example: Substituting with cottonseed meal at $50.00 per ton and corn at $25.00 per ton:

$$\frac{\$2.50 - (.5724 \times \$1.25)}{33.5} = 5.328 \text{ cents}$$

The value of a pound of nonprotein digestible nutrients may be arrived at by the following formula:

$$\frac{\text{Cost of 57.24 pounds corn} - (\text{Value of protein} \times 4.1)}{42.6}$$

Substituting with corn at $1.25 per hundredweight and protein at 5.328 cents per pound:

$$\frac{1.25 \times 57.24 - (4.1 \times 5.328)}{42.6} = 1.167 \text{ cents}$$

Applying the values obtained in this way to the digestible protein and nonprotein digestible nutrients of different feeds, their values may be determined.

By considering the ratio of digestible protein to nonprotein digestible nutrients in relation to the ratio of these two nutrients for corn and cottonseed meal, the relative influence of the prices of corn and cottonseed meal upon the feed in question can be determined. This, together with corrections for the actual digestible protein and nonprotein digestible nutrients, enables the determination of constants for any feed to be applied to the prices of both cottonseed meal and corn for ascertaining the actual value.

Chapter 42

COMMON FEEDS: CHARACTERISTICS AND TREATMENT

Classification of feeds. Feeds are divided into three general groups: (1) roughages, (2) concentrates, and (3) roots. The roughages are divided into hays, of which there are the subgroups legumes and non-legumes, silage, fodders, and straws. The concentrates are classified in three different ways. On the basis of protein content they are (1) high, (2) medium, and (3) low protein concentrates. On the basis of origin they are the cereals and by-products. On the basis of fiber content they are light, heavy, and medium concentrates.

A knowledge of the characteristics and values of the common feedstuffs, together with what constitutes quality in each of them, is essential for intelligent feeding.

ROUGHAGES

Roughage constitutes the basis of the ration for dairy cattle. Without good roughage it becomes difficult to make a satisfactory ration. The proportion of roughage that can be used in the production of milk is largely dependent upon the kind and quality. The quality of roughage is dependent upon the rankness of growth, per cent of the total that is leaves, the way it is cured and stored, and the stage of maturity when it is cut. The highest quality roughage is that which has the finest stems, the greenest color, the highest proportion of leaves, and is cut in the earliest stages of maturity.

Legume hays. Legume hays are the most valuable roughages for the dairy herd. Legumes are characterized by a high protein content, which is so essential in the dairy ration; and they are also more palatable than other roughages. Legumes are also high in calcium content; this insures adequate calcium in the ration when they are fed. The effect of the stage of maturity upon the protein content of alfalfa is characteristic for the groups. The average alfalfa hay contains 10.6 per cent digestible protein; if it is cut before bloom, the digestible protein increases to more than 14 per cent—almost a 40 per cent increase.[1] At one-tenth to one-half bloom the protein content is intermediate. When it is in full bloom, the digestible protein drops to below 9 per cent. Crude fiber changes inversely with the protein in the various stages of maturity. Average alfalfa contains 29 per cent crude fiber, while that cut in the prebloom stage contains about 22 per cent. Palatability of the legume hays varies about proportionately with the earliness of cutting.

[1] Morrison. *Feeds and Feeding*. Morrison Pub. Co., Ithaca, N. Y. 1936.

Of the legumes alfalfa ranks first because of its higher protein content and greater palatability. Next comes lespedeza with about 90 per cent as much protein as alfalfa for comparable qualities, then alsike clover and red clover with 70 to 75 per cent as much. Sweet clover yields more tonnage than other hay crops but makes a rather inferior hay because it is coarse and stemmy. If it is not properly cured sweet clover hay may produce sweet clover disease, which has been discussed previously.

Soybeans, cowpeas, ordinary field peas, and vetch are leguminous plants frequently grown for hay. These rank somewhat lower than alfalfa and clovers for dairy cattle and are mainly to be recommended for hay when other hay crops have failed. The vetchs and field peas may be grown for hay together with oats.

Nonleguminous hays. Nonleguminous hays are characterized by much lower protein and calcium contents and are less palatable than the legumes. Early cut nonleguminous hays have the same comparative advantages over later cut hays as have been shown for the legumes. The manner in which they are cured and stored affect their values in the same way as they affect the legumes. High protein supplements are necessary when any of these hays are fed to milking cows.

Timothy hay is the most common nonlegume hay. Average timothy hay contains about 3 per cent digestible protein and 47 per cent total digestible nutrients, and ranks ordinary from the standpoint of palatability. Early cut timothy hay is fairly palatable and somewhat higher in protein, but is still a low protein feed. It is frequently used as a mixture with the clovers and sometimes with alfalfa.

Kentucky bluegrass is very common in the Northern states. It yields less than timothy but is somewhat more palatable, and contains a little more total digestible nutrients and 50 per cent more protein. Bluegrass in the Northern states frequently establishes itself in alfalfa and other perennial hay crops, finally crowding them out.

Prairie or native hay is a variable product consisting of a number of different species of plants which vary with different localities. When cut in the early stages of maturity, it is on the average comparable to timothy hay.

Johnson grass, quack grass, Western wheat grass, Italian rye grass, brome grass, fescues, and other perennial grasses are used for hay. When cut early, they all have the same feeding values as timothy hay.

Reed canary grass or phalaris grass is frequently used for hay. If this is cut early, a hay of fair quality may be produced. Ordinary reed canary grass hay is coarse and lacks in palatability. Apparently the protein content varies with the soil upon which it is grown, as well as the stage of growth in which it is cut.[1]

A number of nonlegume annuals are used for hay, principally where the regular hay crops fail. All of these compare favorably with timothy hay in composition and palatability. The chief ones in this group are Sudan

[1] Alway and Nesom. Jour. Agr. Res. 40:297. 1930.

grass and the millets. Any of the cereal grains may be cut in the immature stage for hay. Oats are most commonly used for this purpose, and when they are cut in the milk or rough stage of the kernel they make a fairly palatable hay with about 5 per cent of digestible protein. Awned cereals should not be used for hay unless cut when very immature, as the awns may penetrate the lining of the mouth and throat and cause festering.

In years of great scarcity of normal roughages, Russian thistles, marsh grass, cattails, and other like plants have been used for feed. All of these are of very low feeding value and unpalatable. They should be used only in emergencies, as profitable production cannot be expected from these low-grade roughages.

Fodders. Corn and sorghums grown and cut for forage are known as fodders. They may be cut before ears or heads have developed or after considerable seed development has taken place. If seeds have developed, they must be left on the stalks in order to qualify as fodders. Increase in maturity does not detract from the total feed value of fodders as has been noted with the hays. With maturity the fiber of the stalks increases, but this is compensated for by the transfer of nutrients from the stalks into the seeds. The palatability of the stalks, however, decreases with increased maturity.

The fodders, even when apparently dry, contain two or more times the moisture found in cured hay. Largely because of this large moisture content, they deteriorate with age and offer problems in storage.

The fodders are not desirable feeds for milking cows; they rank with the nonlegume hays in this respect. When it becomes necessary to feed fodders, high protein concentrates must be added, and more concentrate must be fed than when good quality legumes furnish the roughage portion of the ration. The wastage, when fodders are fed, is much higher than when good hays are fed. The animals pick out the leaves and the more tender part of the stalk and leave the coarser portions.

Stovers. The portion of the plant that remains after the heads of sorghums or the ears of corn have been removed, is known as stover. Stovers are of low feeding value as most of the nutrients of the stalks have passed into the seeds that have been removed. They also rank very low in palatability. A large proportion of the stovers will be refused unless they are ground, finely cut, or shredded. Except under emergency feed conditions, stovers should not be used in the ration of milking cows.

Straws. As the seeds mature the fiber content of the stems is increased, and the protein, carbohydrate, and fat content are decreased, largely because of a transfer of the latter three to the seed. Since the plant has also been exposed to the weather after growth has ceased, leaching has taken place; this, together with the exposure to sunlight, causes a loss in the soluble material and destruction of the vitamins. The straws coming from mature plants from which the seeds have been removed are characterized by high fiber content and low contents of protein, digestible nutrients, vitamins, and minerals. While there are variations in the feeding values of the different straws, as a whole they are of low value and should

not be included in the rations of milking cows. The feed value of straws is much less than indicated by the total digestible nutrient content as a large amount of energy is required to masticate and digest them. Wheat straw with 35.7 pounds of total digestible nutrients yields only 10 therms net energy, while timothy hay with 47 pounds of total digestible nutrients yields 43 therms of net energy per 100 pounds of hay.

The straws may be considered in groups according to the plants from which they originate, as follows: cereal, legumes, grass hays, flax, and buckwheat.

Oats, barley, wheat, and rye are the common cereal straws. They rank in feeding value in the order named. Oat straw has the softest and most pliable stem and is more leafy than the others. Sometimes oat straw may have a fairly high feeding value, since a portion of it may be immature second growth. Such straw has increased feed value in direct proportion to the amounts of immature plants present. Barley straw ranks next to oat straw, but the awned varieties may cause injury to the mouth and throat. Wheat and rye straws are so woody and of such low feed values that they should never be fed.

Legume straws contain more protein than the cereal straws, but otherwise are no better. Alfalfa, clover, and lespedeza straws are slightly more nutritive than those from beans, peas, and soybeans. Sweet clover straw is usually coarse and unpalatable but may sometimes be of fair quality.

Grass hay straws, such as timothy, bluegrass, red top, the millets, and phalaris, are of slightly higher values than the cereal straws. They have the same value as hay cut when the plant is mature, as but little nutrient material is removed with the seed except in the case of the millets.

Flax straw has a feed value equal to oat straw. There is some danger of prussic acid poisoning from flax straw containing immature flax seeds.

Buckwheat straw has practically no feed value and may cause digestive trouble.

CONCENTRATES

To no other class of livestock are concentrates so important as to high producing cows. Because of the high energy requirements of the heavy milking cow, it is necessary that a large portion of the ration consist of concentrates. As the capacity for feed intake is limited by the amount of dry matter, it is obvious that concentrates containing more than 50 per cent more digestible nutrients than do roughages make possible much greater nutrient intake. Since the protein requirement of the milking cow is higher than that of any other farm animal, in order to supply the protein needs it becomes necessary to add high protein concentrates to the ration, especially when nonleguminous roughage is fed. The kind of concentrate to select depends upon the needs for completing the requirement of the ration, and also upon the availability of the concentrate. Concentrates may be divided into two groups—those consisting of the whole or ground seeds of plants, and those that are the by-products of various plant and

animal products. There are large numbers in each one of the two groups, but only the more common ones will be considered here.

SEEDS OF PLANTS

Corn is the most commonly used concentrate for dairy cattle. In the corn belt it is the cheapest source of energy, being a heavy yielding crop. Corn ranks first among the grains as a source of energy, having more than 80 per cent total digestible nutrients; and it is also the lowest in protein, with 7.0 per cent digestible protein. In addition to being the most palatable of all feeds, it is also one of the heaviest, and if fed in quantities larger than 5 or 6 pounds daily, it should be mixed with lighter feeds, such as oats or bran. For average milking cows corn may be used satisfactorily as the only concentrate with a good quality of alfalfa hay.

Corn and cob meal. When the entire ear of corn is ground, the meal is known as corn and cob meal. The ground cob has no food value; therefore the feed value of corn and cob meal is as much less than that of corn as there is cob in the meal. Because the cob lightens the mixture, corn and cob meal is preferred to ground corn where large amounts are fed. It is also sometimes more convenient to grind the entire ear than to shell the corn before grinding.

Barley is slightly lower in total digestible nutrients than corn, but it is higher in protein. Feeding trials have shown barley to be about equal to corn for milking cows. Barley is very palatable, although it is not quite so palatable as corn. Like corn, barley is heavy, and when fed in large quantities should be mixed with lighter feeds.

Oats are excellent for dairy cows but are frequently overrated as a source of energy. On account of the hulls, they contain about 12 per cent less total digestible nutrients than corn. Oats are extremely variable; light weights may be as much as 30 per cent less valuable than normal oats. Oats are highly palatable and may be fed alone in any amount because of their lightness. For the same reason they serve a very useful purpose in lightening the concentrate mixture. Oats may be used as the only concentrate with legume hay for average producing cows.

Wheat is used for feed in years of low prices, and frosted and shriveled wheat unsuited for milling purposes is used constantly. Wheat is equal to corn as a feed for cows, but it is less palatable and heavier. It should always be mixed with some lighter feed. The food value is apparently not affected by frost or shriveling.

Rye has practically the same composition and consequently the same nutritive value as wheat; it contains all the other characteristics, except that it is unpalatable. It is also quite frequently contaminated with ergot, which adds to the lack of palatability, and if present in large quantities may "dry-off" cows.

The sorghums—kaffir, feterita, milo, and others, except the sweet sorghums—rank with corn in composition and feeding value. They are slightly less palatable than corn.

Emmer and spelt resemble oats in composition, palatability, lightness, and in feed value.

Buckwheat has a lower nutritive value than oats; it is quite unpalatable, and will cause eruptions on the skin of animals.

Flax seed, because of its high oil content, contains nearly 100 pounds of total digestible nutrients per 100 pounds, the highest energy value of any natural seed. It is also high in protein. Flax seed is usually too high priced to be used as a feed, but when it is used it is found to be palatable. Flax seed is very laxative, and it is sometimes used for that purpose. It produces a soft butter when fed to milking cows.

Soybeans are increasing in importance as a feed for dairy cows. They have the highest protein content (33 per cent digestible protein) of any natural seeds. While soybeans are fed principally as a source of protein, they are high in total digestible nutrients (86 per cent), exceeding corn in this respect. They are palatable and also heavy in character. The ground beans are likely to turn rancid if kept for any length of time in warm weather.

Cowpeas, peas, velvet beans, and other leguminous seeds are sometimes fed dairy cattle. They are excellent sources of protein and are quite palatable.

PLANT BY-PRODUCTS

By-products of corn. Corn is used extensively in the manufacture of corn meal and starch, which gives rise to a number of by-products used for feeding. From the manufacture of starch, corn gluten meal, corn gluten feed, and corn oil meal are secured. From the manufacture of corn meal hominy feed is a by-product.

Corn gluten meal, which consists chiefly of corn gluten, contains about 43 per cent of protein and is, therefore, one of the high protein concentrates. It is palatable, but a heavy feed.

Corn gluten feed differs from gluten meal in that besides the corn gluten, it also contains the corn bran plus some other portions of the corn kernel. It contains only about 26 per cent of protein. Like corn gluten meal it is an excellent source of protein.

Corn germ oil meal is the residue of the corn germ after the oil has been expressed. It differs from other oil meals in having a much lower protein content.

Hominy feed is equal to corn in feed value; it has about the same composition, and it is somewhat lighter than corn.

By-products of wheat. In the milling of wheat for flour more than 25 per cent of the total weight of the wheat goes into by-products.

Wheat bran, from the outer coatings of the wheat kernel, is one of the most commonly used dairy feeds. Wheat bran contains about 12 pounds of digestible protein and 70 pounds of total digestible nutrients per 100 pounds. It is fairly palatable, mildly laxative, and bulky. The latter makes it a valuable feed in lightening up heavy concentrate mixtures. Wheat bran is also one of the best sources of phosphorus. Wheat bran comes in

two forms: pure wheat bran, and standard wheat bran. The standard wheat bran contains the finely ground screenings of the wheat. The feed value of the two is equal.

Standard wheat middlings, or shorts, consist of finer particles than bran and include the wheat germs. Standard wheat middlings are slightly higher in both protein and total digestible nutrient content than bran but are not so desirable as bran for feeding dairy cattle. Because of the finer particles and some flour, they are heavy and have a tendency to form into a sticky mass when wetted.

Wheat germ meal has recently assumed some importance as a feed. Besides being a good source of protein, wheat germ meal is a good source of vitamin E.

By-products of barley. The chief by-products of barley are brewers' grains and malt sprouts.

Brewers' grains are fed both wet and dried. Dried brewers' grains contain about 23 per cent of digestible protein and 65 per cent of total digestible nutrients. They lack somewhat in palatability and should be mixed with more palatable feeds. Because of their bulkiness, they may be used in place of oats or bran in the ration.

Wet brewers' grains vary greatly in water content; the dry matter is the same as for dried brewers' grains. Care must be taken in warm weather that wet brewers' grains are not permitted to decompose in the mangers as odors are produced that may affect the milk. Up to 30 to 35 pounds of wet brewers' grains may be fed to milking cows daily.

By-products of oats. In the manufacture of oatmeal the hulls and the oats shorts are removed, and these form what is called oat feed. This material has approximately the feed value of timothy hay.

Cottonseed by-products. The two chief by-products of the cottonseed are the meals and the hulls. After the cottonseed oil is expressed, the cottonseed residue is graded upon the basis of the protein content, which varies from 25 to 43 or more per cent. The difference in protein content is largely due to variations in the amount of hulls present, as the hulls contain only about 2 per cent of protein. When the total protein is below 36 per cent, the product is known as cottonseed feed. When all the hulls are included, the protein content is 25 to 30 per cent and the product is known as whole pressed cottonseed. The hulls have but little feed value.

Cottonseed meal is one of the cheapest and most widely used sources of protein supplement in the ration. Outside of the cotton territory the higher protein grades are usually the cheaper sources of protein. Cottonseed meal has gained the reputation of being poisonous to cattle. This has been shown not to be the case.[1] Animals restricted to cottonseed meal and hulls have suffered from deficiency diseases due to insufficient vitamin A, but when good roughage is fed in connection with cottonseed meal, there is no danger from injury even where ten or more pounds are fed

[1] Halvorson and Sherwood. N. C. Agr. Expt. Sta. Tech. Bul. 39. 1930.
Huffman and Monroe. Jour. Dairy Sci. 13. 1930.

daily. Cottonseed meal likewise has been shown not to be constipating, as some people have claimed.

Flax seed by-products. Linseed oil meal, the residue left when oil is extracted from the flax seed, varies from below 30 per cent to over 37 per cent of protein; it should always be purchased upon the basis of its protein content. In the making of the new process oil meal the oil is extracted with solvents, and therefore the meal contains less oil and more protein than in the "old process," where the oil is expressed by pressure. Linseed oil meals, particularly the old process meals, are laxative, and are especially valuable where nonlaxative feeds are fed. Because of its popularity, protein is usually higher priced in linseed oil meal than in cottonseed meal.

Soybean and peanut oil meal. Soybean oil meal is the residue left when oil is extracted from the soybean. Soybean oil meal contains from 40 to 48 per cent protein, and is the highest protein plant product. The meal is palatable and the protein is of high quality.

Peanut oil meal is of about the same composition as soybean oil meal.

Screenings. Screenings are so variable in composition and values that only the most general statements can be made. Screenings should always be bought on the basis of the chemical composition, and should never be bought if they contain noxious weed seeds or seeds that produce off flavors in the milk. Flax screenings or other cereal screenings may contain a large proportion of broken seeds together with some weed seeds of high feed value.

Roots, tubers, pumpkins, and molasses. Roots, tubers, and pumpkins may be considered as watered concentrates on a dry matter basis. They analyze about the same as low protein concentrates. Mangles, rutabagas, stock carrots, beets, and pumpkins contain only about 10 per cent dry matter. Ten pounds of these may, therefore, take the place of one pound of grain. These very succulent feeds are greatly valued by feeders for high producing cows. Potatoes contain about twice the amount of dry matter as roots and pumpkins. They are not relished by cattle as well as are roots. Roots may be fed up to 60 or more pounds per day and potatoes up to 40 or 50 pounds. Turnips and rutabagas should be fed immediately after milking to avoid tainting the milk.

Beet pulp, the dried residue of the sugar beet after extraction of the sugar, is valued highly by feeders of milking cows. It has about 10 per cent less total digestible nutrients than corn. Most people prefer to feed the dried beet pulp after it has been resoaked, with about four pounds of water to one pound of the dried pulp. Dried beet pulp may, however, be mixed with the concentrate mixture without soaking to give equally good results. Beet pulp with molasses has slightly higher feeding value than without molasses.

Molasses. There are two kinds of molasses used in the feeding of livestock: cane molasses, a by-product from the making of cane sugar; and beet molasses, a by-product from the making of beet sugar. Both of these have essentially the same feed value, about 70 per cent of that for corn.

The chief difference between the two is that beet molasses is much more laxative because of its salt content and must be fed more carefully than cane molasses. Cows should be gradually accustomed to beet molasses, and should never be fed more than three pounds per day.

The greatest value of molasses is in its appetizing effect. It is probably the most palatable feed for cattle; and because of its liquid nature, it may be used in improving the palatability of many otherwise unpalatable feeds. Mixed with two or three parts of water to improve the palatability and increase its consumption, it may be sprinkled over roughage in the manger.

ANIMAL BY-PRODUCTS

Tankage and meat scraps may be fed as a source of protein. However, these are not palatable and many cows will refuse mixtures containing but small amounts of these two high protein concentrates.[1]

Fishmeal has been used as a protein supplement in dairy cattle rations with fair success. Like tankage and meat scraps, it is not palatable, and in some cases, may reduce the fat content of the milk. It is an excellent source of both calcium and phosphorus.

Skim milk is an excellent source of protein, and some energy, although not very much.[2] On a dry matter basis skim milk contains 35 per cent of digestible protein and 86 per cent of total digestible nutrients. Ten pounds of skim milk equals one pound of dry matter. One gallon of skim milk has been found equal to one pound of linseed oil meal for milk production. At first cows do not like skim milk. It may be fed by mixing it into the grain mixture to form a slop.

VARIOUS TREATMENTS OF FEEDS

Ensiling

One of the oldest treatments of feed to preserve and improve the feeding value is that of ensiling, or preserving green fodders in pits. In the United States the beginning of silage making goes back to 1875, when the first silo was constructed in Michigan. Since that time the interest in silos and silage has grown until about a million silos have been constructed.

Silage fermentation.[3] Silage is made from green material through natural fermentation or by acid preservation.

In natural fermentation bacteria, in the absence of air, break down the sugars of the green plant material principally into lactic and acetic acids, with traces of other acids and some alcohols. The acid so developed prevents putrefactive bacteria from acting and decomposing the material. In the fermentation process some of the dry matter is lost, being converted into carbon dioxide and water. The exact amounts lost by this action are not known, but probably the losses due to the silage processes do not exceed 10 per cent of the total dry matter.

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1 Unpublished data of the author's.
2 Eckles and Schultz. Jour. Dairy Sci. 14:189. 1931.
3 Hunter and Bushnell. Kans. Agr. Expt. Sta. Tech. Bul. 2. 1916.

Acid preservation of silage: the A. I. V. Process. Some plants, such as grasses and legumes, do not contain enough sugar for fermentation of the necessary amount of acid needed for preservation. As a result attempts at ensiling legumes and grasses frequently terminate in failure. Recently a method has been developed and patented by Virtanen of Finland in which a mixture of hydrochloric and sulphuric acid is added to the green material as it is put into the silo, to bring the acidity to that caused by normal fermentation. This process is known as the A. I. V. Process. The proponents for this method claim that in addition to enabling the making of silage with surety from low sugar plants, it reduces the losses from fermentation to practically nothing. Further, it has been shown that the acid preservation of the green material preserves the carotene much better than can be done through normal fermentation or dry curing of material.

The Minnesota Station [1] has shown that the addition of phosphoric acid accomplishes the same result as the A. I. V. acids, and in addition adds phosphorus, which may be needed both as a nutrient and fertilizer. Special equipment for adding the acid must be used with both of these methods. Skilled attention is also needed, that the right amounts of acids are added.

Preservation by addition of molasses or sugar.[2] Several experiment stations have reported successes in preserving the material as silage by adding molasses or sugar solutions as the material is put into the silo. By artificially increasing the sugar content of the low sugar material enough acid is formed for preservation of the silage. From 40 to 60 pounds of molasses per ton of green legumes or grasses has been found adequate. Recent reports indicate that the addition of molasses preserves the carotene nearly as well as the A. I. V. Process. Molasses has the advantage over the inorganic acids in that it is easier to handle, and if too much is added, no harm is done; whereas if too much inorganic acid is added, the material may be ruined for feed.

The molasses may be diluted with one or two parts of water and the solution run into the silage cutter from an elevated barrel.

Advantages of silage. While a dozen or more advantages may be listed for silage the most important ones are as follows:

1. The real advantage of a silo on a livestock farm is that it enables the saving of feed much of which would otherwise be wasted or would deteriorate in value. The silo enables the saving of feed in at least four different ways:

   a. While the loss of dry matter in the silo amounts to about 10 per cent, much greater losses are experienced in curing and storing such crops as corn, sorghums, and sunflowers. The Colorado Station reported 43 per cent losses in dry matter of corn left in small shocks. Eckles [3] also found a loss of 43 per cent in dry matter for corn left in the field for 134 days.

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[1] Unpublished data of Rogers.

[2] Horwood and Wells. Mich. Agr. Expt. Sta. Quart. Bul. 19, No. 2. 1936. Bender. Certified Milk 12:9. Aug., 1937.

[3] Eckles. Dairy Cattle and Milk Production. New York. 1923.

b. The silo makes possible the saving of legume and other hay crops during rainy seasons, when attempts to make hay would result in a forage of decided inferior quality.
c. It makes possible the use of plants that would otherwise not be eaten, such as weeds. When weeds of the cornfield are put into the silo, the otherwise unpalatable weeds may be eaten, and the seeds are destroyed.
d. Wastes in refused feeds are reduced or eliminated. When, for example, dry corn fodder is fed, from 15 to 34 per cent of the total weights are refused by cattle, while practically nothing is refused when corn silage is fed.

In the corn belt corn yields the largest amount of total digestible nutrients, and in order to make efficient use of the crop, it must be ensiled. In mature corn 60 to 70 per cent of the nutrients are in the ears and from 30 to 40 per cent in the stalks. By ensiling the whole crop 30 to 40 per cent more nutrients are made available for livestock than when only the corn grain is used.

2. Less storage space is needed for storing a given amount of dry matter in silage than in the dried form. Approximately 2.5 times as much dry matter can be stored in the same space in the form of silage as when stored in the dry form.

3. Silage furnishes the cheapest and most satisfactory source of succulent feed.

4. Silage may be kept indefinitely without any deterioration, while roughages stored in the dry form continue to deteriorate with the length of time stored.

5. By ensiling, the crop is removed from the soil immediately, leaving the soil free to be worked.

Disadvantages of silage. While on most farms silage is an economical feed, there are conditions under which it becomes too expensive to warrant use. Recent work has shown that when a good quality of legume hay is fed, silage is not essential for optimum milk production. Therefore, where a greater yield of alfalfa can be secured than of corn or sorghums and where it is not necessary to grow the latter, silage is not to be advised except in so far as it may be advisable to place legumes in the silo. The large amount of expensive equipment needed, together with the large amount of labor required for filling the silo, frequently brings the cost of silage above that of an equal amount of dry matter in hay. In Iowa the cost on a dry matter basis is reported to be about the same for corn silage and alfalfa hay. In Wisconsin, Minnesota, and New York the costs of silage are reported as being considerably higher than for equal dry matter in alfalfa hay.

The belief that silage is an essential feed for high milk production has kept a number of dairymen in the Northern states growing corn for silage. In many places it is uneconomical because corn yields are too low in comparison with clovers or alfalfa.

Requirements for good silage. The first requirement for making good silage is a good airtight silo. Air leaking through the walls or doors permits spoilage of silage by molds and bacteria. Before the silo is filled, all cracks

in the walls should be stopped, to avoid extensive losses from spoilage. The next most important factor is the quality of the material with which the silo is filled. The silage process does not increase the digestibility of the material; it merely preserves the nutrients already present. It is, therefore, important that the materials to be ensiled contain the optimum amount of nutrients. For crops with large seed development the more nearly mature they are when ensiled, the greater will be the yield and the higher the digestible nutrients. When legumes and grasses are ensiled, the same stage of maturity that is best for hay making will produce the best silage.

Another important factor in the making of good silage is the water content of the material. If the silage is too dry, water must be added or the material will not pack sufficiently to prevent spoilage from molds and other microorganisms. If the silage is too watery, the material should be permitted to partially dry out before being ensiled or too sour silage is likely to be produced.

Another very important consideration is that the material to be ensiled must contain sufficient sugar for proper fermentation, or spoilage will result from putrefaction. Corn, sorghums, and sunflowers always have enough sugars, but many other crops require the addition of sugar in some form, such as molasses, or the addition of the proper amounts of some acid to insure perfect keeping.

Value of silage in the ration. The value of silage in the ration of milking cows has been somewhat overemphasized. The claims that succulence contributed materially to the economic production of milk and that silage has values in addition to its digestible nutrient content are not warranted by facts. The value of silage is limited to its digestible nutrient content, plus the benefits of a slightly laxative effect when fed with some rations. The Connecticut [1] and Minnesota [2] Stations have shown that silage fed in tests did not increase milk production, and increased costs per 100 pounds of milk.

Definite experimental evidence is lacking as to whether silage stimulates the appetite; it is also not known whether more nutrients are consumed in roughage when silage forms part of the ration than when only dry roughage is fed. When hays of low quality are fed, the addition of silage increases the amount of dry matter consumed because of its greater palatability. When the hays fed are of good quality, it is questionable whether the addition of silage will increase the consumption of dry matter in the total roughage.

Silages made from anything but legumes are low in their protein content, and more high protein concentrates must be fed cows receiving such silage as part of the ration than when a legume hay is the only roughage fed.

Silage may be fed as a supplement to pastures during the summer. Unless the silage is made from legumes, a protein concentrate must be

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[1] White and Johnson. Conn. Agr. Expt. Sta. Bul. 198. 1934.
[2] Cole, Donovan, and Allen. Jour. Dairy Sci. 20:221. 1934.

supplemented, particularly when the pasture grasses are mature and dried up.

Corn silage. By far the majority of silage used is made from corn. The feeding value of corn silage depends upon the stage of maturity when cut. Well matured corn will make a silage containing over 20 per cent of total digestible nutrients, whereas silage made from immature corn with no ear formation may contain as little as 12 per cent total digestible nutrients. Average corn silage contains about 17 per cent total digestible nutrients, or is about one-third the value of hay. Being low in protein, corn silage should be compared with the grass hays: three tons of average corn silage equal one ton of hay in feed value. Corn silage is the most palatable of the silages, cows having consumed over 90 pounds daily.

Dried corn fodder or stover may be ensiled. If adequate water is added, normal fermentation will take place and a fairly normal silage will result. Such silage is a little less palatable than that made from green material. The fodder silage has a feed value equal to normal corn silage. The stover silage has a much lower feed value.

Sorghum silage.[1] Next to corn, sorghums are the most important silage crops. The grain sorghums—kaffir, milo, feterita, etc.—are similar to corn in composition and produce silage equal in value to corn. The sweet sorghums will make silage of good quality if they are mature when ensiled. Such silage has about 90 per cent the value of good corn silage. If the sweet sorghums are immature when ensiled, a sour, less palatable silage results.

Silages from grasses and legumes.[2] In the past it has been held that where weather conditions are favorable for the making of good hay, there is no advantage in putting up grasses and legumes in the form of silage. It was also generally believed that not as much dry matter would be consumed in silage as in the well-cured hay. Recent experiments[3] with legumes cut at the same time, one part being ensiled and the other put up as hay, showed that more digestible protein and total nutrients were obtained from the silage than from the well-cured hay. Significantly more milk with a higher vitamin A and carotene content was also obtained from the silage. The silage was found to be at least as palatable as the hay and in some cases more palatable. There was no significant difference in the cost of the two methods. These results indicate that it may be well to put up more hay crops as silage, particularly where difficulty is experienced in proper curing. By ensiling the hay crops, cutting can be done irrespective of the weather and therefore before the plant becomes too mature; curing is difficult in many places when these crops are put up in the form of hay.

It has long been recognized that the best way to salvage legumes with coarse stems and plants that are too mature is to make them up as silage.

[1] Reed and Fitch. Kans. Agr. Expt. Sta. Cir. 110.
Becker and Gallup. Okla. Agr. Expt. Sta. Bul. 177.

[2] Perkins. Ohio Agr. Expt. Sta. Bul. 370.
Eckles. Mo. Agr. Expt. Sta. Bul. 162.
Reed and Fitch. Kans. Agr. Expt. Sta. Bul. 217.

[3] Rpt. Chief Bur. Dairy Ind. 1947.

Sweet clover and soybeans, because of woody stems, are most commonly ensiled.

Grasses and legumes have low sugar contents and, consequently, acid is formed slowly in the silage making. This gives rise to decompositions that produce stout, undesirable odors under most conditions. These odors do not detract from the palatability but are objectionable from the human point of view. By wilting [1] the material so that not over 70 per cent and not less than 60 per cent of moisture is present, excellent grass and legume silage can be made without any preservatives being used. Soybeans [2] and peas that have seed formed in the pod have enough sugar for normal fermentation.

When the fresh material is placed in the silo, the development of offensive odors may be prevented by the addition of either sugar or acid. The most common sugar used is molasses, of which 40 to 60 pounds diluted and mixed with the fresh cut material will develop the preserving acids in sufficient quantities to produce pleasantly smelling silage. About 25 pounds of powdered whey has proven satisfactory but more difficult to properly incorporate in the freshly cut material. Acids may be added directly to the material. Hydrochloric and sulfuric acid mixtures are commonly used in Northern Europe, where the technique is known as the A. I. V. process after A. I. Virtanen, its developer. Acids should be added to bring the *p*H value down to about 4.0. Different materials will require different amounts of the acid. A fair amount will be about 15 gallons of a 2-normal solution of equal parts of the two acids per ton of green material. Usually linae is added to the silage when fed to counteract the effects of the acid. These acids are detrimental to equipment and clothing. Phosphoric acid is used by some with satisfactory results. This acid not only preserves the silage but is also a good source of phosphorus in the ration and for the soil where additional amounts of this element is needed.

Legume silages will have similar T. D. N. values to corn silage with comparable amounts of moisture. The protein content, however, will be much higher. For grass silage, the T. D. N. values are similar to legumes but the protein values will vary with the stage of maturity when cut. Young immature grass silage may have up to 14 per cent protein on a dry matter basis while mature hays may be as low as 4 per cent.

Pea vine silage [3] has about the same feeding value as alfalfa silage. The odor of this material is often offensive but not harmful to cattle nor will it flavor the milk from feeding. Sweet clover silage may produce the sweet clover disease from the same substances that are sometimes produced in the sweet clover hay and which prevents the blood from clotting.

Sunflower silage.[4] In cooler climates sunflowers yield much more nutrients than corn and are frequently used for silage. Sunflower silage

[1] Shepherd. B.D.I.M. Inf.—38. 1946.
[2] Becker, Neal et al. Fla. Agr. Expt. Sta. Bul. 255.
[3] Moseley, Stuart, and Graves. U. S. Dept. Agr. Tech. Bul. 116.
[4] Bohstedt et al. Wis. Agr. Expt. Sta. Bul. 425.
Cole, Donovan, and Allen. Minn. Agr. Expt. Sta. Spec. Bul. 181.
Nevens. Ill. Agr. Expt. Sta. Bul. 253.

has only about 70 per cent of the feeding value of good corn silage and is rather unpalatable. Where corn can be grown successfully, sunflowers should not be used for silage.

Beet top silage.[1] Beet tops may be preserved in piles, trench silos, or regular silos to form a fair silage with feeding values of approximately 65 per cent of that of corn silage. Beet tops are decidedly laxative and contain oxalic acid. Although they are palatable, because of these facts not more than 30 to 35 pounds should be fed daily.

Other Fermenting or Predigesting Processes

At various times patented processes for fermenting or predigesting feeds have appeared upon the market. Claims are made by the promoters that these processes increase the digestibility of roughages. Some even claim that roughages are converted into concentrates. The process consists of placing the "ferment" with the chopped roughage into a tank, adding water, and allowing the mass to ferment.

Various experiments have shown that no value is added to the feed by any of these processes. In many cases there are actual losses of nutrients by the "process."[2]

Grinding, Cutting, Cooking, Soaking

Grinding grain.[3] It is well known that cattle do not masticate food thoroughly when eating. Hard seeds are therefore swallowed without being chewed, and since, unlike the roughages, they are not regurgitated and rechewed, they pass on through the digestive tract. On account of their hardness, seeds like corn, barley, and oats are not sufficiently acted upon by the digestive juices to be digested, and a large portion passes through undigested. The Purdue Station [4] found that from 20 to 25 per cent of the oats and 30 to 35 per cent of the corn fed, were recovered in the feces when these grains were fed unground to dairy cows. Even larger portions of whole sorghum seeds pass through the digestive tract.

Grinding to medium fineness has been found to produce the best results. Cracked corn and crushed oats showed losses of 5 to 10 per cent and 1 to 2 per cent respectively. Finely pulverized feeds produced 5.4 per cent less milk than medium ground feeds, and in addition cost more to grind. Whole corn and oats produced 11.2 per cent less milk than these feeds did when ground to medium fineness, and cracked corn and crushed oats 5.8 per cent less.

For calves up to six or eight months of age it is not necessary to grind the grains fed; up to that age, calves masticate their food quite thoroughly.

Grinding roughage.[5] Grinding roughage for dairy cattle has been

[1] Jones. U. S. Dept. Agr. Farmers' Bul. 1095.
[2] Bul. 96, new series Canadian Dept. of Agr.
[3] Hayden and Monroe. Ohio Agr. Expt. Sta. Bul. 470.
[4] Wilbur. Purdue Agr. Expt. Sta. Bul. 372.
[5] Reed and Burnett. Mich. Agr. Expt. Sta. Quarterly Bul. Aug., 1936. S. Dak. Agr. Expt. Sta. Bul. 252.

advocated by some who claim increased digestibility of the ground roughage. This claim is not borne out by a large number of experiments, where it has been found that grinding sometimes decreases the digestibility. In the few cases where increased digestibility has been reported, the difference was so slight as to be insignificant. Another claim for grinding the roughage is that animals cannot select one part of the roughage and refuse other parts. This is substantiated, but for heavy milking cows it is probably best that they not be forced to eat the coarse refused roughage.

Any advantages that may be gained by the reduction of the amounts of roughage wasted is more than offset by the cost of grinding. Grinding costs range from $1.75 to $3.50 per ton, depending upon the costs of labor and power.

The ground roughage has been found to be less palatable than the unground roughage.

Cutting, chopping, and shredding.[1] Inasmuch as cutting roughage is a rather inexpensive process, many people find it advantageous in preventing wastage of coarse roughages. The cut roughage, too, is more palatable than when ground. Many people cut hay for storage in the barn by running it through a silage cutter to increase storage capacities.

When fodders are fed, chopping or shredding is advisable. The refused fodder stalks are hard to handle, while the refused portion of the cut or shredded material makes good bedding.

Cooking feeds. From time to time equipment for cooking feeds has been offered on the market with claims that cooked feeds are both more palatable and more digestible. Numerous experiments have not only proved such claims false, but have shown that protein is made less digestible by heating. The labor and fuel used in cooking feeds are therefore wasted.

Soaking feeds. Hard, unground grains are made more digestible by thorough soaking. If grinding facilities are available, grinding the grains and feeding them dry is to be preferred to soaking. Feeding concentrates as a slop has no advantages, but increases the labor requirement and dirties the mangers.

Digestion processes. With the claim that the digestibility of feed stuffs, particularly roughages, can be increased, several different proprietary processes have been offered. For most of them the roughage is chopped, mixed with the concentrate, and a ferment (enzyme) is added. Warm water is then added at the rate of two pounds per pound of feed mixture, and the mass is put into a small silo-like container and permitted to ferment for several days. Experiments have shown that little if any improvement in digestibility can be expected from such processes.

[1] Bohstedt et al. Wis. Agr. Expt. Sta. Res. Bul. 102.

Chapter 43

FEEDING DAIRY COWS IN THE BARN

BASED UPON THE EXTENT THAT FEED MUST BE FURNISHED THE COW IN THE stall or barn, dairy feeding problems are met in the three following conditions:

1. Where all the feed must be furnished in the barn.
2. Where a portion of the feed requirements comes from pastures.
3. Where all the feed is furnished by pasture.

The problems incident to the latter two will be discussed in the following chapter, and therefore only the problems concerned with furnishing all the feed will be considered here.

The problems encountered in feeding milking cows in the barn lend themselves to further subdivision into three groups. The basis for this division is the ratio of concentrates to roughage that is fed. The three groups of problems are encountered under the following conditions:

1. Where liberal amounts of concentrates are fed.
2. Where no concentrates or only limited amounts are fed.
3. Forced feeding for maximum production, such as under Official Test conditions.

Feeding cows with liberal amounts of concentrates: economy of liberal feeding. As the daily milk yield of a cow increases, the amount of milk produced per unit of feed consumed also increases. This is clearly shown in the following table, where it is seen that when a 1,200 pound cow is fed 15.11 pounds of total digestible nutrients, a daily milk production of 20 pounds may be maintained, and only 1.32 pounds of milk is produced per pound of total digestible nutrients. If this cow is capable of producing 60 pounds of milk daily, 28.52 pounds of total digestible nutrients would

ECONOMY OF LIBERAL FEEDING. POUNDS OF MILK PRODUCED PER POUND OF TOTAL DIGESTIBLE NUTRIENTS AT VARIOUS LEVELS OF MILK PRODUCTION FOR A 1,200 POUND COW PRODUCING 4 PER CENT FAT MILK

Milk yield, lbs.	20	40	60
T.D.N. for maintenance, lbs.	8.40	8.40	8.40
T.D.N. for production, lbs.	6.71	13.42	20.12
Total	15.11	21.82	28.52
Lbs. milk per lb. T.D.N.	1.32	1.84	2.1

be required, and 2.1 pounds of milk would be produced per pound of total digestible nutrient. Unless the feeds supplying the total digestible nutrients required for the daily milk production of 60 pounds are much more expensive than those required for the lower production, the higher production is also more economical.

Liberal feeding does not pay when the costs of concentrates are unusually higher in price than roughages. The conditions under which this holds true will be discussed later.

Function of concentrates in the ration. Concentrates serve two general purposes in the feeding of dairy cattle. They permit a greater nutrient intake than roughages alone will; and they constitute the chief source of protein when low protein roughages are fed. Through the use of concentrates increased nutrient intake is effected in two ways: by substituting concentrates weight for weight for roughages, and by increasing the total food intake through the greater palatability of concentrates.

TOTAL DIGESTIBLE NUTRIENTS IN VARIOUS PROPORTIONS OF ALFALFA HAY AND CONCENTRATE COMBINED TO EQUAL 40 POUNDS, WITH AMOUNT OF 4 PER CENT MILK THAT MAY BE PRODUCED; CONCENTRATE IS 2 PARTS OATS, 1 PART CORN, AND 1 PART BARLEY

AMOUNTS		DIGESTIBLE NUTRIENTS			NUTRIENTS ADEQUATE: MILK PRODUCTION
Hay	Concentrate	Hay	Concentrate	Total	
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
40	0	20.56		20.56	36.2
35	5	17.99	3.72	21.71	39.7
30	10	15.42	7.44	22.86	43.1
25	15	12.85	11.16	24.01	46.5
20	20	10.28	14.88	25.16	50.0
20	25	10.28	18.60	28.88	61.0

Concentrates, as the term implies, contain more digestible nutrients per unit of weight than do roughages. As a cow's capacity for feed intake is limited, it is obvious that a point is reached at which the limit of food intake in roughage does not contain the required nutrients. Concentrates are then added to furnish additional nutrients. The preceding table shows that by changing the ration from 40 pounds of alfalfa to 20 pounds of alfalfa and 20 pounds of a concentrate mixture, the digestible nutrient intake is increased from 20.56 pounds to 25.16 pounds. This changes the nutrient intake from just enough to produce 36.2 pounds of 4 per cent milk to enough to produce 50 pounds when the cow weighs 1,200 pounds.

Concentrates, as a rule, are more palatable than roughages, and the total feed intake may be greatly increased through the feeding of concentrates, particularly if the roughages are of poor quality. By increasing the concentrate allowance from 20 pounds to 25 pounds when 20 pounds of alfalfa hay is consumed, the milk production is increased from 50.0 pounds to 61.0 pounds. (See the preceding table.)

Where low protein roughages such as the grass hays and corn or sorghum silage are fed, high protein concentrates are essential to bring the protein content of the ration up to the requirements. Regardless of how much low protein roughage may be consumed and how adequate the total digestible nutrients may be from this source, the milk production, due to the inadequacy of protein, will be very limited. For economical production a high protein concentrate must be added regardless of cost.

Rules for feeding. As has been previously stated, the only sure way of ascertaining whether a milking cow obtains adequate nutrients is to calculate her needs by use of the feeding standard and ascertain the nutrients in the ration fed. There are, however, so-called thumb rules that are fairly satisfactory as guides to adequate feeding. In the past the following rules have been used extensively:

1. Allow all the roughage a cow will eat.
2. With a good grade of roughage such as legumes with or without silage, allow 1 pound of concentrate for each 3 to 3½ pounds of milk testing below 4 per cent of fat, and 1 pound of concentrate for each 2½ to 3 pounds of milk testing above 4 per cent of fat.
3. With poor roughage such as prairie or grass hays with or without silage, feed 1 pound of concentrate for each 2½ to 3 pounds of milk testing below 4 per cent of fat, and 1 pound of concentrate for each 2 to 2½ pounds of milk testing above 4 per cent of fat.

Another rule is to feed one pound of concentrate daily for each pound of butterfat produced in a week.

These rules are relatively accurate for moderate producing cows, but supply too much nutrient for the low producers and not enough for the high producers. To correct this fault and to partly account for greater use of high quality roughage, new rules have recently been devised by the Bureau of Dairying [1] and the Minnesota Station.[2] These rules are based upon the fact that a cow eating all the good quality roughage she can consume secures sufficient nutrient to produce varying quantities of milk in addition to maintenance requirements. Concentrate feeding does not begin until the milk yield has reached a point where all of the nutrients supplied in the roughage are used. Beyond this point the concentrate is supplied to furnish the nutrient actually required for the additional milk produced. The recommendations differ for the various breeds, as is shown in the table on page 499.

Feed all the good quality roughages such as alfalfa, clover, or soybean hay with or without silage, and then concentrates according to the preceding schedule.

Although these rules are an improvement upon the former, they are inadequate for high producing cows. In most cases when more than five pounds of concentrates are fed, the amount of roughage consumed declines. With higher producing cows, therefore, more concentrate must

[1] Woodward, Shepherd, and Graves. U. S. Dept. Agr. Misc. Pub. 130.

[2] Gullickson and Fitch. Feeding the Dairy Herd. Minn. Agr. Expt. Sta. Bul. in press.

AMOUNTS OF CONCENTRATES TO BE FED WHEN HIGH QUALITY ROUGHAGES ARE FED

Breed	Feed no Concentrate Until Daily Milk Production Exceeds:		Pounds of Concentrate for Each Additional Pound of Milk:	
	Bureau of Dairying	Minnesota	Bureau of Dairying	Minnesota
	Pounds	*Pounds*	*Pounds*	*Pounds*
Holsteins	16	20	0.40	.42
Brown Swiss	14	18	0.45	.45
Ayrshire	14	16	0.45	.45
Guernseys	12	12	0.55	.55
Jerseys	10	10	0.60	.60

be fed to replace the lessened nutrient intake due to the smaller amounts of roughage consumed. An additional two-thirds pound of concentrate should be allowed for each pound of decreased hay consumption or three pounds of silage (3 pounds of silage are equal to one pound of hay in total nutrients).

When the hay is of low quality, the rules do not apply. If only one and one-half pounds of hay are consumed per 100 pounds of live weight, the nutrient intake is barely enough to supply the maintenance requirements, and all the nutrients required for milk production must be furnished in the concentrate.

When the roughage is high in protein content. When the roughage is a high quality legume hay, such as alfalfa, clover, lespedeza, and soybean, the problem of feeding dairy cows becomes quite simple. If these hays are of good quality, the cows will consume large enough quantities to obviate the need for high protein concentrates. When concentrates are plentiful and are relatively no higher in price than the hay, the best results with high producing cows are secured when the roughage is limited to two pounds per 100 pounds of live weight and concentrates supply the remainder of the nutrient requirements. A 1,200 pound cow receiving 25 pounds of alfalfa hay secures enough nutrients to produce 13.3 pounds of 4 per cent milk besides the maintenance requirements. There is enough protein for an additional 26.6 pounds of milk. (See the table on page 500.)

It is obvious that the protein content of the concentrate is not of much concern. A mixture of two parts oats, one part barley, and one part corn contains 9.35 per cent of digestible protein and 74.4 per cent of total digestible nutrients. This mixture furnishes adequate protein for all levels of production when the total digestible nutrient requirements are met and alfalfa is fed at the rate of two pounds per 100 pounds of live weight.

While corn as the only concentrate would furnish adequate protein for high producing cows receiving two pounds of alfalfa hay per 100 pounds of live weight, better results are obtained with a mixture of concentrates from three or more plants. A mixture of home-grown grains consisting of two parts oats, one part barley, and one part corn will give excellent re-

NUTRIENTS IN EXCESS OF MAINTENANCE REQUIREMENTS FURNISHED BY VARIOUS LEVELS OF ALFALFA HAY CONSUMPTION FOR A 1,200 POUND COW, AND THE AMOUNTS OF 4 PER CENT MILK FOR WHICH THIS IS ADEQUATE

Excess Digestible Nutrients			Amount of Milk for Which Nutrients Are Adequate	
Amount of Hay	Protein	Total Digestible Nutrients	Digestible Protein	Total Digestible Nutrients
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
15	.804	−.16	17.2	0
20	1.324	1.90	28.6	5.6
25	1.844	4.48	39.9	13.3
30	2.364	7.05	51.2	21.0
35	2.884	9.63	62.4	28.7
40	3.404	12.20	73.7	36.4
50	4.444	17.30	96.3	51.7

sults. Although such a mixture furnishes adequate protein with alfalfa hay or any other high quality legume, additional protein in the concentrate is believed by many to give better results for cows milking more than 50 pounds daily.

When a mixture of high and low protein roughages is fed. A mixture of high and low protein roughages is commonly fed. The most common low protein roughages fed with legumes are the corn and sorghum silages, although frequently corn fodder, grass hays, and other low protein roughages are fed with legumes. Legume hays are also frequently mixed with low protein roughages. As it takes approximately three pounds of silage to equal the total digestible nutrient content of one pound of hay, one-half of the hay is usually replaced by three times that amount of silage.

If at least one pound of alfalfa hay or any equally good legume hay is fed per 100 pounds of live weight, a concentrate mixture containing 10 per cent digestible protein is adequate. When low protein roughages constitute a considerable portion of the ration, the amounts of roughage consumed will be less than when only a good legume is fed. When such is the case more concentrates must be fed.

When low protein roughages are fed. When the roughage is of the low protein variety, less will be consumed and more concentrates must be fed than when high quality high protein hays are fed. It is also necessary to add a higher protein concentrate for low producing cows than for high producing cows. Reference to the table on page 501 reveals that the low protein content of timothy hay (which is typical for the group) is the limiting factor for milk production. A 1,200 pound cow consuming 25 pounds of timothy hay secures enough total digestible nutrients to produce 10.7 pounds of 4 per cent milk, but not enough protein to supply the maintenance requirement. This is contrasted with the same amount of alfalfa hay (see the table on page 500), which supplies enough protein for 39.9 pounds of 4 per cent milk, and enough total digestible nutrients

NUTRIENTS IN EXCESS OF MAINTENANCE REQUIREMENTS FURNISHED BY VARIOUS LEVELS OF TIMOTHY HAY INTAKE FOR A 1,200 POUND COW, AND THE AMOUNTS OF 4 PER CENT MILK FOR WHICH THIS IS ADEQUATE

Amount of Hay	Excess Digestible Nutrients		Amount of Milk for Which Nutrients Are Adequate	
	Protein	Total Digestible Nutrients	Digestible Protein	Total Digestible Nutrients
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
15	−.321	−1.20	0	0
20	−.176	1.20	0	3.6
25	−.031	3.60	0	10.7
30	.114	6.00	2.5	17.9
35	.259	8.40	5.6	25.0
40	.404	10.80	8.7	32.2
50	.694	15.60	15.0	46.5

for 13.3 pounds. For the cow producing 10.7 pounds of milk when consuming 25 pounds of timothy hay, more than one-half pound additional digestible protein must be furnished. When the one-half pound of digestible protein has been added, the nutritive requirements for maintenance and for production of 10.7 pounds of 4 per cent milk have been met. For each additional pound of milk production .46 pounds of a 10 per cent digestible protein concentrate must be added. A 10 per cent concentrate furnishes the nutrient requirements for 4 per cent milk.

The amount of high protein concentrate to be added to a low protein roughage depends upon how much of the latter is fed. If 17½ pounds of timothy hay is fed the 1,200 pound cow, only .21 pounds of digestible protein need be added; but the .46 pounds of the 10 per cent protein concentrate must be fed for each pound of milk produced. When the cow produces 40 pounds of 4 per cent milk, one pound of corn gluten feed and 17 pounds of a 10 per cent digestible protein concentrate are required.

Feeding cows on limited quantities of concentrates. Limiting the ration to roughage alone or with a small amount of concentrate supplement will not permit the highest milk production with cows capable of large production. There are conditions, however, where production of milk from roughage alone is more profitable than higher production secured from liberal concentrate supplements. As to whether roughage alone will be more profitable than when concentrates are added depends upon the relative yields of roughage and concentrates, the relative cost of the two, the quality of the roughage, and the market on which the dairy products are sold.

The relative yields per acre and costs of total digestible nutrients in various common crops are given in the following table. The total yields per acre are the greatest and the costs per 100 pounds of digestible nutrients are the lowest for alfalfa. Corn silage ranks next to alfalfa in yield of nutrients per acre but costs more than twice as much per unit of total

digestible nutrients. Alfalfa hay produces about two and one-half times as much total digestible nutrients per acre as barley and wheat, and nearly three times as much as oats. Corn grain yields about twice the nutrients that barley and wheat do. Except for corn, the cost of total digestible nutrients in grains is from two to three times as great as in alfalfa. The other roughages, while not as high yielders as alfalfa, are still cheaper sources of nutrients than grain.

Relative milk yields from alfalfa alone and with grain. Several experiments have been conducted to show the relative yields of milk from alfalfa hay alone and with various levels of grain. Moseley, Graves, and Shepherd reported on the yields of Holstein cows fed alfalfa alone, alfalfa[1]

Average Yield per Acre of Various Crops, Average Cost of Production per Acre, and Cost of Producing 100 Pounds of Total Digestible Nutrients in the Various Crops, as Summarized from Published Results of Crop-Production-Cost Studies in Eight Counties in Three States[1]

Crop	Yield per Acre		Cost of Production		Labor per Acre, Man-hours	Total Digestible Nutrients Produced per Man-hour
	Feed	Total Digestible Nutrients	Per Acre	Per 100 Pounds of Total Digestible Nutrients		
	Bushels	*Pounds*	*Dollars*	*Dollars*	*Number*	*Pounds*
Corn:						
Grain	49.90	2,283	26.21	1.15	17.89	127.6
	Tons					
Silage	6.27	2,220	38.22	1.72	27.52	80.7
	Bushels					
Oats	41.75	941	21.82	2.32	10.21	92.2
Wheat	22.24	1,069	26.05	2.44	12.15	88.0
Barley	28.77	1,097	20.96	1.91	10.15	108.1
	Tons					
Clover hay	1.53	1,558	17.81	1.14	7.70	202.3
Timothy hay	1.23	1,193	15.75	1.32	6.21	192.1
Mixed clover and timothy	1.42	1,312	17.39	1.33	8.13	161.4
Alfalfa hay	2.61	2,694	23.62	.88	16.7	161.3
Soybean hay	1.55	1,662	30.07	1.81	15.1	110.0

with limited grain supplement, and alfalfa with full grain supplement.[2] The limited grain group received one pound of grain for each six pounds of milk produced, while the full grain group received one pound of grain for each three pounds of milk. The cows on alfalfa alone produced 70 per cent and those on limited grain 93.2 per cent as much milk as when on full grain feed. The number of cows required for producing the equivalent amounts of milk to 100 cows on full grain, together with the acres re-

[1] Graves and Shepherd. U. S. Dept. Agr.
[2] Moseley, Graves, and Shepherd. U. S. Dept. Agr. Tech. Bul. 116.

quired to furnish the feed and the cost of producing the feed, is given in the table on this page.

It is seen that the feed cost for producing any given quantity of milk increases with the amount of grain fed. The number of acres required to produce the necessary feed also increases with increased grain feeding. Although a lower average milk yield per cow is obtained from feeding roughage alone, a larger yield of milk per acre of feed is attained.

Plane of Feeding	No. of Cows	No. of Acres Required	Cost of Producing the Feed	
			Dollars	Per Cent of Full Grain
Roughage alone	143	402	6,025.98	74.2
Limited grain	107.3	444	6,833.77	84.2
Full grain	100	517	8,117.50	100

The preceding statement is based upon the supposition that both grain and roughage are grown on the farm where they are used and that the relative yields of roughage and grains are those commonly observed. When either roughage or grains are purchased, the relative prices of the two should govern the amounts of concentrate fed. When concentrates are relatively higher in price than roughages, less grain and more roughage should be fed. The tables for evaluating feeds, given in the Appendix, serve as a valuable guide in what feeds to purchase, as well as to indicate the relative costs of roughage and concentrates.

Relation between price of butter fat and profit from feeding roughage alone. Profit depends mostly upon the cost of the feed and the price received for the product. When the prices for the product are low, it is necessary that feed costs also be low in order to maintain a margin of profit. It has been shown that when butterfat prices are from 20 to 30 cents per pound, roughage alone brings the largest returns per cow over feed costs. When butterfat sells at 40 to 60 cents per pound, the limited grain ration produces the largest returns over feed cost. With butterfat at 70 or more cents per pound the full grain ration produces slightly larger net returns per cow than does the limited grain ration.

Essentials for satisfactory returns from limited amounts of concentrates or roughage alone. As to whether roughage alone will produce satisfactory results in feeding milking cows is dependent upon a number of factors. The first and absolutely essential requisite is that the roughage be of excellent quality and palatable. Unless roughage is of high quality and palatable, insufficient quantities will be consumed for adequate nutrient intake. Except for very immature grass hays, one should never attempt to feed anything but high quality legumes as roughage only rations.

When roughage only or limited grain rations are fed, a phosphorus supplement should be furnished all milking cows, because roughages as a whole are likely to be low in phosphorus content. A good quality of

bone meal furnished *ad libitum* is advised. Unless a phosphorus supplement is furnished, the appetite for feed declines, with further decrease in phosphorus intake as well as other nutrients.

The relationship between the price of the product and the advisability of limiting or entirely omitting grain supplements has been discussed just previously.

Another important consideration in determining the proportion of concentrates and roughage that should be fed is that of general farm management. Different soil types and weed and other problems may dictate the growing of certain cereal crops although they may not be as high yielders as certain roughages. Cereal crops also have values above the nutritive value of the grain. Straw must be credited with a value for bedding.

In order to insure maximum nutrient intake from feeding roughage with or without limited grain allowance, larger quantities must be offered than are consumed. The higher producing cows should be allowed enough so that up to 10 per cent of the hay offered is refused. The refused hay may be fed horses, young stock, or dry cows, and therefore is not wasted.

Feeding for maximum production. Feeding for maximum production is, as a rule, not profitable; but it is desired in making the largest possible records, as in Official Testing. While with increased production the coefficient of efficiency increases (see Chapter 37), other costs increase out of proportion to the gain in efficient utilizaton of the feed. In order to secure the maximum production, more expensive feeds must be used, and it becomes necessary to feed and milk more frequently. More work is required for other care, and greater barn expense is incurred in furnishing more comfortable surroundings.

In order to secure maximum production, it is essential that the cow be well fitted before calving, and that the maximum amounts of nutrients be furnished following calving. This gives rise to a number of problems not encountered in feeding for economical milk production. The more important of these problems are the choice of feeds, the number of times to feed daily, getting the cow on full feed following calving, and preventing the cow from "going off" feed.

By careful fitting before calving and through expert care and liberal feeding when in milk, the production of good cows may be increased 50 to 100 per cent over that secured under good normal conditions.

Cows on Official Test consume more feed than is required by the feeding standards for the milk produced. The greater feed consumption is obtained through selection of the most palatable feeds and frequent feeding. Official Test cows are usually milked three and four times daily and fed grain each time milked.

Fitting the cow for Official Test. It has previously been shown that the condition of a cow at calving time has a marked influence upon the level of milk yield following. In preparing a cow for maximum production it is essential that she be in as good a condition as possible. A dry period of at least two months is essential. Many breeders prefer longer dry periods.

During the dry period, as much concentrate should be fed as is necessary to get the cow into the best possible condition of flesh at calving time. The stored fat will then serve as a reservoir to be drawn upon for milk production following calving. The amount of concentrate to be fed will vary with the condition of the cow and her ability to handle feed. From 12 to 20 or more pounds are generally fed daily during this period. There is great variance in opinion as to the contents of the concentrate mixture that will give the best results. As protein cannot be stored to any extent in the body, the amount of protein in the fitting ration is not of great importance.

The amounts of energy, calcium, phosphorus, and vitamin D are important. Because the cow must consume such large amounts of concentrate during the fitting, special attention must be given to palatability and bulk, as well as to the slightly laxative quality the feed should possess. While literally hundreds of different rations may be used, the following serves as an example of a good fitting ration:

100 pounds of corn meal
100 pounds of hominy feed
200 pounds of ground barley
100 pounds of bran
100 pounds of linseed oil meal

This ration is high in energy and very palatable. Ample phosphorus intake is assured in the bran and linseed oil meal. The latter two also make the ration slightly laxative, while the bran adds the necessary bulk.

A bright, well-cured alfalfa hay as a roughage will insure adequate calcium and vitamin D. Silage may be fed in addition to alfalfa hay, although this is not necessary.

Feed and care at calving. Several weeks before calving the "test" cow should be placed in the box stall where she is to be kept for the following year, so that she may become thoroughly accustomed to the surroundings.

About a week or ten days before calving it is well to change the concentrate portion of the ration to one of two parts each of bran and ground oats and one part oil meal. This ration is fairly laxative and is believed by many to prevent the severe congestion of the udder that is commonly experienced with highly fitted cows immediately after calving. Soaked beet pulp as an addition to the ration at this time is preferred by many. This ration should be continued for a few days following calving, and then a change should be made to the concentrate mixture to be used during the year.

One of the real problems in connection with the Official Test cow feeding is that of bringing the cow on full feed. Only five or six pounds of the concentrate mixture should be fed to begin with on the third to fifth day following calving. The feed should then be increased daily not to exceed one-half pound until such time as full feed is attained. Attempts at bringing a cow to full feed too rapidly usually results in the cow going "off feed." Once a cow goes "off feed" it becomes necessary to greatly reduce

the concentrate allowance and begin all over the problem of getting her on full feed. As soon as a force fed cow shows any tendency of not cleaning up all the feed offered, the amounts offered at the next feeding should be drastically reduced to avoid her going "off feed."

"Test cow" ration. Many "test cow" feeders claim to have secret combinations of feed that produce better results. The great variety of rations used to feed test cows and the excellent results obtained through their use tend to discredit such claims. A good test cow ration fulfills the following requirements: it is palatable, it contains the right bulk, it is made up of a large variety, it is fairly high in protein content, and is slightly laxative.

As high producing cows on test must frequently consume more than 30 pounds of grain daily, it is important that the mixture be palatable.

GRAIN MIXTURES FOR COWS ON TEST [1]

	No. 1	No. 2	No. 3	No. 4
	Pounds	*Pounds*	*Pounds*	*Pounds*
Corn meal	200	100	...	...
Cottonseed meal	100	...	200	100
Distillers' dried grain	...	...	500	200
Dried beet pulp	100	...	...	...
Gluten feed	100	...	300	125
Gluten meal	...	100	...	...
Ground oats	100	200	...	125
Hominy feed	...	...	400	...
Linseed oil meal	100	200	200	80
Wheat bran	100	300	400	200

Because variety aids in making the mixture palatable, five or more feeds should be used in the mixture. Many improve the palatability of the concentrate by adding two to three pounds of molasses either by pouring the molasses over the grain feed or by diluting it with two parts of water and mixing it with the concentrate.

While too high protein content of the ration should be avoided because it may result in possible damage to the animal, more protein should be furnished the test cow than is called for by the feeding standard. Protein has a stimulating effect upon milk production, and although protein is expensive this is taken advantage of in feeding test cows. When a legume hay is used as the roughage, the concentrate should have from 16 to 20 per cent protein.

To lighten the concentrate mixture bran, oats, beet pulp, and dried brewers' grains are used quite freely. Morrison advises a fat content of 5 per cent for test cow rations. Ground flax and ground soybeans are frequently used to increase the fat content of the ration.

A succulent feed is of more importance in the test cow ration than in

[1] NEVENS. Ill. Agr. Expt. Sta. Circ. 272.

the regular dairy ration. Succulence may be provided in silage, roots, or beet pulp. Roots and beet pulp are preferred over corn silage. Up to 50 or 60 pounds of sliced mangels may be fed daily. When beet pulp is the only source of succulence, ten pounds of the dried pulp soaked in water are usually fed daily.

While hundreds of different test cow rations have been used successfully, the table above, taken from Nevens, serves as a guide to the type of rations used.

One hundred pounds of distillers' grains may be replaced by 100 pounds of gluten feed or 200 pounds of wheat bran.

Chapter 44

FEEDING COWS ON PASTURE

IMPORTANCE. ONE OF THE MOST IMPORTANT BUT GENERALLY NEGLECTED factors in economical milk production is that of pasture. Good pasture is capable of supporting higher milk production than ordinary barn feeding. Most cows when turned out on good pasture from good barn feeding will increase their milk yields. The average pasture, however, is good for but a short time. The rest of the season it is an adequate source of nutrients for the milking cow and must be supplemented by hay, concentrate, or soilage crops.

The adequacy of pasture for milk production depends upon the maturity, abundance, and the kind of plants. Supplying an abundance of pasture in the right stage of maturity throughout the entire pasture season is a real problem. The difference in the rate with which plants grow due to the season and the amount of rainfall influence pasture values from one part of the season to another. This gives rise to the problem of properly supplementing pasture in seasons of inadequacy.

Nature of young pasture grass.[1] Pasture grass has often been referred to as a concentrate; this is partially correct. Young pasture grass, regardless of species or variety, is characterized by relatively low fiber, high protein, and high water contents. Grasses of less than three weeks' growth average about 22 to 25 per cent protein, less than 18 per cent crude fiber on a dry matter basis, and about 25 per cent dry matter. Crude fiber content is the chief criterion of whether a feed is a roughage or a concentrate. The crude fiber content of young pasture grass is intermediate between that of a roughage and a suitable concentrate for dairy cows. The crude fiber content of average alfalfa hay is 29 per cent; and of a mixture of two parts oats, one part barley, and one part corn, it is 7.3 per cent. A ration consisting of equal parts by weight of alfalfa and this grain mixture contains the same amount of crude fiber that young pasture grass does.

The protein content of young pasture grass is more than adequate to supply the needs of the highest producing cows. The nutritive ratio is less than 1:3 or 1:4 where a nutritive ratio of 1:6 or 7 is adequate for average producing cows.

The mineral content of pasture grass is dependent upon the species of plants and the fertility of the soil. Legumes are always certain to contain enough calcium, while nonlegumes on acid soil may not. The phosphorus content of both legumes and nonlegumes is dependent upon the phosphorus content of the soil upon which they are grown. Regardless of the

[1] ELLENBERGER, NEWLANDER, AND JONES. Vt. Agr. Expt. Sta. Bul. 295. 1929.
LUSH. Proc. Am. Soc. An. Prod. Pages 91–94. 1932.
ORR. Minerals in Pastures. Rowett Research Institute. 1927.

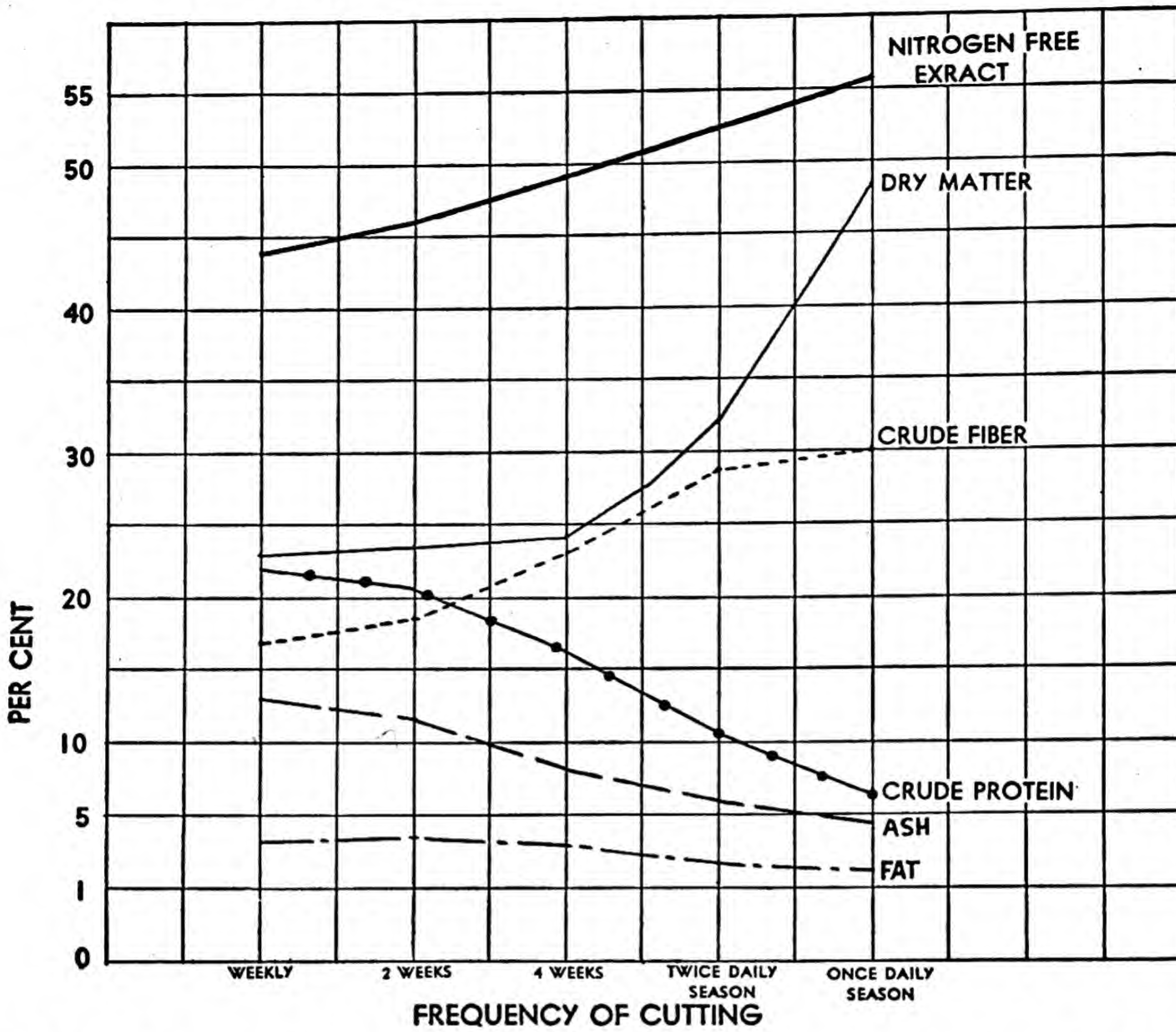

Fig. 111. Effect of maturity upon the composition of pasture grass. With the exception of the line for "dry matter," the values are on a dry matter basis.

species or the fertility of the soil, young pasture grass contains more of both calcium and phosphorus than do mature plants. Only in extreme soil deficiencies will there be any danger of either calcium or phosphorus deficiency in milking cows grazing on abundant young pasture grass.

Green pasture grass furnishes an abundance of carotene, the precursor of vitamin A. While young growing grass is devoid of vitamin D, there is no danger of animals grazing on grass suffering from lack of sufficient vitamin D, as the exposure of the animal to sunlight while grazing insures adequate vitamin D formation in the body.

Relation of the stage of maturity to composition. Pasture grass declines rapidly as a source of adequate nutrients for high milk production because of the lowered nutritive value due to advance in maturity, and also because of scarcity due to a slowing up of growth. Figure 111, adapted from reports from Vermont,[1] pictures graphically what happens to the composition of mixed pasture grass with advance in maturity. Crude fiber increases from about 17 per cent for the two weeks' old grass to 30 per cent for the mature grass; protein decreases from about 22.5 per cent to about 7

[1] Ellenberger, Newlander, and Jones. *Op. cit.*

per cent, all on a dry matter basis. Ash and fat likewise decrease with advance in maturity. Nitrogen free extract and dry matter increase with maturity.

Obviously the mature grass is too low in protein content to satisfy the requirements of milking cows. The increased fiber content and the accompanying lowered palatability reduce the total nutrient intake, resulting in the declines in milk production so generally experienced where such pastures are not properly supplemented.

While legume grasses when young are of the same chemical composition (except for calcium, in which they are higher) as the other pasture plants, they do not decline so rapidly in protein content with advance in maturity. Mature legumes as a rule contain enough protein for milk production.

Amount of grass a cow will consume. The amount of grass a cow will consume from grazing depends upon the palatability and abundance of the pasture, and also upon the inherent capacity of the cow. Only meager experimental evidence is available as to the amount of grass a cow will graze. In one experiment where Holstein cows were fed grass clipped from irrigated pastures, from 122 to 152 pounds of the green grass were consumed per day.[1] This was calculated to supply sufficient nutrients to maintain the cow and the milk production of 37 pounds daily.

Woodward [2] grazed Holstein and Jersey cows on orchard grass and white clover pastures, and on lespedeza orchard grass and white clover. He found wide variations in the amounts of grass consumed. Holsteins consumed more grass than the Jerseys but not in proportion to the body weight. The amount of grass consumed depended upon the luxuriance of the pasture. A cow cannot graze more than 6 per cent of the total grass on one acre and a limit of 150 pounds for one day, regardless of the luxuriance of the growth. For a cow to graze the limit of her capacity, the pasture must have 2,500 or more pounds of grass per acre.

Inspection of Woodward's data reveals that the cows consume more total weight of grass and more total digestible nutrients from the pasture in the early spring than during the summer. The amounts eaten are in agreement with the total amount of grass per acre.

Yields of nutrients and milk from pasture. The yields from pasture vary within wide limits due to the influence of a number of factors. The type and stand of the herbage, soil fertility, climatic conditions, and closeness of grazing are very important factors influencing the yields of pasture in nutrients and milk. Vermont [3] reports a range of 128 to 3,506 pounds of dry matter eaten per acre for various types of pastures studied. The milk yield reported per acre for these pastures varied from 120 to 3,160 pounds.

The yield of a plant used for pasture is usually less than when it is permitted to grow to maturity. Different plants vary in this respect.

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[1] GRAVES, DAWSON, KOPLAND, AND MOSELEY. U. S. Dept. Agr. Tech. Bul. 381. 1933.
[2] WOODWARD. Jour. Dairy Sci. 19:347. 1936.
[3] ELLENBERGER, NEWLANDER, AND JONES. *Op. cit.*

Studies reported by Cornell University [1] in which the grass was clipped gave the following yields of dry matter per acre and the percentage of dry matter in the grass as compared to the same cut for hay:

YIELDS OF GRASS CLIPPINGS

Grass	Compared to Grass Cut for Hay	Dry Matter per Acre	Grass	Compared to Grass Cut for Hay	Dry Matter per Acre
	Per Cent	*Pounds*		*Per Cent*	*Pounds*
Timothy.......	40.5	1,454	Bluegrass.......	113.1	1,387
Red top........	76.3	1,557	English rye grass	70.0	1,557
Meadow fescue..	74.3	1,665	Brome grass....	70.2	1,690
Orchard grass...	59.9	1,711	Tall oat grass...	51.0	2,044

The Ohio Station [2] reports good permanent pasture yielding slightly less dry matter per acre than a rotation of corn, wheat, and hay, but more protein. White,[3] on the other hand, reports slightly more total digestible nutrients (1,560 pounds) and nearly three times as much protein (344 pounds) from good pasture as from a rotation of corn, oats, wheat, and hay which averaged 1,463 pounds of total digestible nutrients and 119 pounds of digestible protein per acre. Under irrigation, yields up to 7,000 pounds of dry matter per acre have been reported. It is clear from the foregoing data that no average figure can be given representing the yields of pasture. It is also obvious that under favorable conditions, pastures may yield nutrients that compare favorably with those from rotation crops at much less expense.

Cost of pastures. While the yield of good pasture in terms of total digestible nutrients compares favorably with that of ordinary rotation crops, the costs of pasture are much lower. Misner,[4] comparing the relative economy of producing milk on pasture and during the winter, found the feed costs on pasture to be $0.097 and on dry feed to be $0.380 per day per cow. The product was worth $0.34. White, comparing the labor costs per acre of pasture and rotational crops of corn, oats, wheat, and hay, found the former to be $0.70 and the latter $14.90 per year.

Effect of grazing upon yields of pasture. Yields of pasture grasses are greatly reduced by too early grazing in the spring, too close grazing, and by trampling. Turning the cows out on pasture before the grass has had a good start reduces the yield for the rest of the season. In addition the early pasture grass is low in dry matter, and consequently the cows secure inadequate nutrients. Milk production on the early grass is made, to a large extent, from the body reserves, which in many cases become exhausted by the time the pasture is in its prime. Under these conditions

[1] WIGGANS. Cornell Agr. Expt. Sta. Bul. 424. 1923.
[2] DODD AND SALTER. Ohio Agr. Expt. Sta. Ext. Bul. 154.
[3] WHITE. Jour. Am. Soc. Agron. 21:589. 1929.
[4] U. S. Dept. Agr. Misc. Pub. 194. 1934.

maximum milk yield from good pasture cannot be attained. The height which pasture grass should have attained before pasturing begins varies with the type of grass. Four inches for bluegrass and prairie grasses and six inches for other grasses are the probable minimum heights for the best results.

Too close grazing has the same depressing effect upon pasture yields that too early grazing has. For the plants to make rapid growth, a definite minimum amount of leaves are required. Over-grazing reduces the amount of herbage per acre and, as a result, the cows must cover a larger area to secure the needed grass. This also results in more danger from trampling.

Pasture management. On most dairy farms no crop producing land will yield larger returns from intelligent management than will pastures. As a rule pastures are the most neglected of all the crops. The land unsuited for cultivation is set aside for permanent pasture, as it should be; but, as a rule, no effort is put forth for its improvement. Pastures in crop rotations are usually given a little more attention, but further effort toward improvement will bring fruitful results. The more important considerations in pasture improvement are avoiding too early grazing, avoiding overgrazing, seeding, introducing the best varieties of plants, applying the appropriate fertilizer, and controlling weeds.

The effects of too early grazing and overgrazing have already been discussed. Too early grazing is avoided by keeping the cattle off the pasture until the herbage has a sufficient start. Overgrazing can be avoided by keeping the number of cattle down to the carrying capacity of the pasture. The effects of overgrazing may also be avoided by the practice of rotational grazing. When the pasture is divided into two or more parts and grazing is permitted on but one part at a time, the grass is given a rest period for developing foliage; this results in an increased rate of growth. This system of grazing also furnishes more luxuriant pasture for the cattle and less damage to the grass from trampling.

Space does not permit a discussion of the best species and varieties for pasture in the different sections. However, different sections require different mixtures of plants for the best results. When pastures are part of the crop rotation plans, those species and varieties of plants should be chosen that give the best results. Permanent pastures should be seeded frequently to produce the right density of the most desirable species.

In many instances, the addition of fertilizer to pastures produces astounding results. When fertilizers are needed, the application of the right fertilizer not only increases the yield of pasture herbage, but produces a feed of higher nutritional value.

Control of weeds in a pasture is of importance from two standpoints. First, since weeds greatly reduce the yield of the desirable pasture herbage, the yields are greatly increased by weed control. Second, by weed control in pastures the off flavors which many weeds impart to the milk may be avoided. Weeds may be fairly well controlled by periodic mowing. This also improves the general quality of the pasture because the more mature

and less palatable pasture plants are removed, permitting young growth to be made available for grazing.

Pasture supplements. The pasture should be supplemented for high producing cows and for all cattle when the grasses become short. As has been previously indicated, the best pasture is not adequate for more than 40 to 50 pounds of milk yield daily; and cows milking more than that should have a concentrate supplement. A larger problem in supplementing pastures is met when the pasture yields decline to a point of inadequacy for the grazing cattle. Due to the change in the rate of growth of pasture herbage with different parts of the season and the differences in rainfall and other climatic conditions, the yields of pasture vary greatly with the advance of the pasture season. The pasture of the United States Department of Agriculture Experiment Station at Beltsville, Maryland, in May yielded twice as much as in June and three times as much as in August and September. In Florida a steady increase in pasture yields from May to the highest point in August is reported. In Vermont the yield of pasture grass is reported to be the greatest in June, with but slightly lower yields for May, July, and August. In the North Central states the pastures are the best in June, drop to a low in July and August, and then improve in September and early October.

These differences in the rate of growth of pasture grasses present a real problem. If sufficient cattle are pastured during the season of optimum growth to utilize the growth, there will be a shortage of pasture during the other parts of the season. If the number of cattle is limited for the pasture during the slower growing season, the quality of the pasture will be lowered because the plants will become mature during the rapid growing season. To get the most out of pastures, the number of cattle should be adjusted to correct pasturing during the optimum growth, and supplements should be furnished for the rest of the pasture season. Declining pastures may be supplemented in various ways. The more common supplements to pasture are soilage crops, other pastures, concentrates, hay, and silage.

Soilage crops. Soilage crops cut and fed when green are often used as a supplement to pasture and sometimes as the only source of roughage. Alfalfa, clover, corn sorghum, Sudan grass, and other crops may be used. Soilage crops are like pasture grass in composition and may be planted in succession to furnish an abundance of green material to supplement declining pasture. Such crops as alfalfa and the clovers, which may cause bloat when pastured, may be fed as soilage crops with little danger. The yields as soilage crops are also greater than when pastured. The advantages of "soiling," however, are more than offset by the cost in cutting, hauling, and feeding the green material.[1]

Supplementary pastures. One of the most satisfactory means of meeting the problem of supplementing declining pastures is to furnish supplementary pastures. Suitable acreage should be provided of some crop

[1] McCandlish. Ia. Agr. Expt. Sta. Bul. 201.

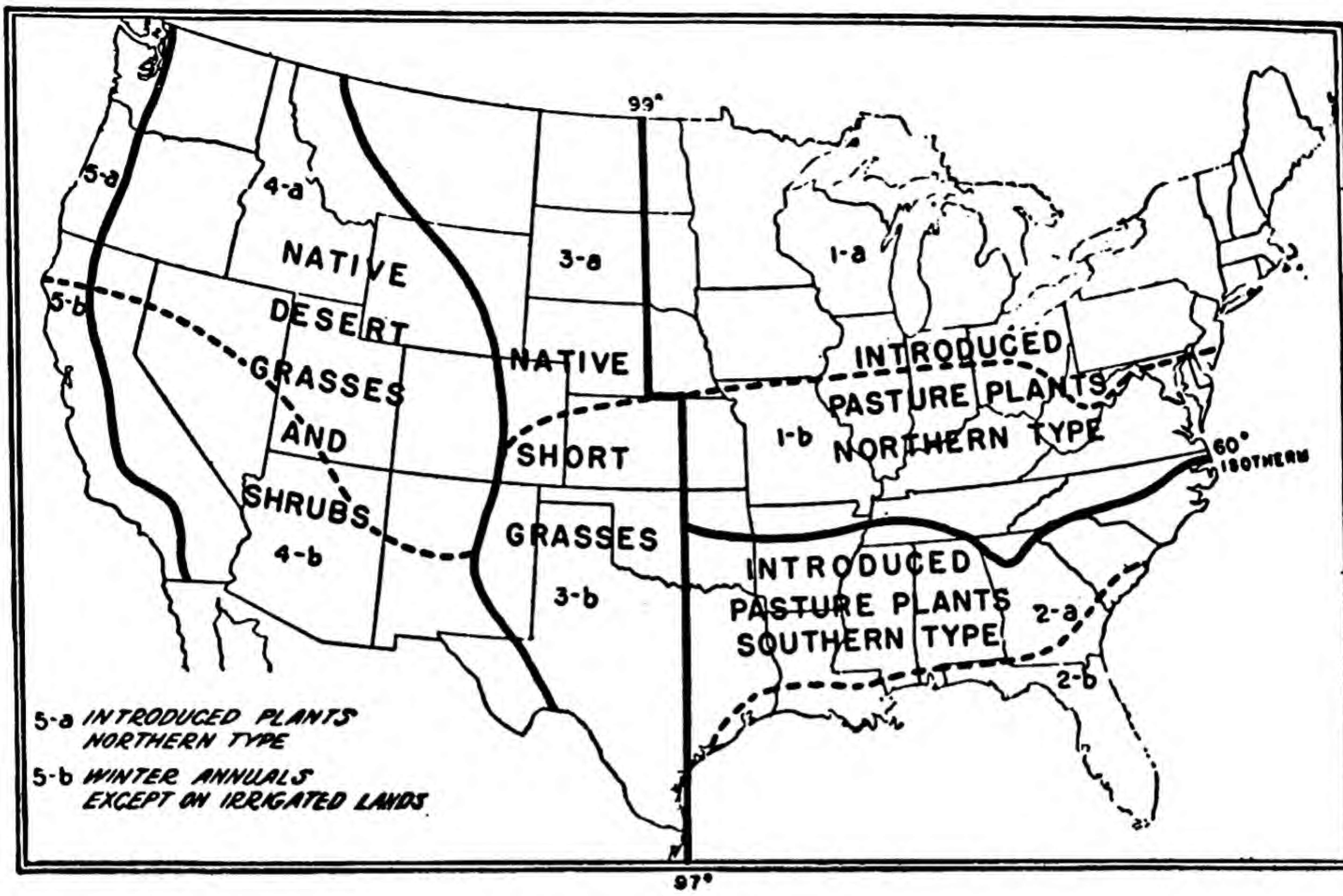

Fig. 112. Pasture regions of the United States. The pasture plants adapted to each of these regions are given in the tables on pages 516 and 517.

having a maximum growth during the period of poor growth for the regular pasture. At the proper time the cattle may be turned on the supplementary pasture to give the regular pasture a rest and chance to recuperate. When rotational grazing is practiced, the supplementary pasture adds one more plot to the rotation. Sudan grass, soybeans, clovers, millet, and many other crops may be used for these pastures.

Concentrates. Concentrates form the most common, although expensive, supplement to pastures. On the best of pastures cows producing over 40 pounds of milk daily should be allowed concentrates at the rate of one pound for each two to four pounds of milk produced above 40 pounds. With poorer pastures all milking cows should be fed concentrates unless some other supplement is available. Unless the pasture grass is mature in the latter part of the pasture season, no attention need be paid to the protein content of the concentrate supplement as green herbage furnishes an abundance of protein. If the pasture is mature and consists largely of grasses, then it is necessary to furnish a concentrate with at least 10 per cent of digestible protein.

The amount of concentrate to feed milking cows on pasture depends entirely upon the condition of the pasture. In many cases the grain allowance on pasture should be that recommended for winter feeding.

Hay and silage as pasture supplements. Good quality hay and silage are excellent supplements to pasture. Trials have shown these to be cheaper and as desirable as soilage crops. When they are used as supplements to

pasture, hay and silage should be fed in the evening after the cows come from pasture. Feeding in the morning before going on pasture reduces the cow's desire for grazing, and the amounts eaten on pasture are reduced.

Pasture crops. A large variety of plants are used for pastures. Some of these are much better suited for some regions and localities than for others, and some are limited to certain regions. It is not possible to consider here the many plants used for pasture, but a few of the more important ones, together with their advantages and disadvantages, will be discussed. For this purpose pastures may be divided into the following groups: permanent mixed pastures, other permanent pastures, legumes, supplemental and emergency pastures, and cereal grain pastures.

Permanent pastures. According to Vinall and Enlow, the United States is divided into five main pasture regions on the basis of the type of vegetation to which they are adapted.[1] Each region is subdivided into two sections, as indicated in Figure 112. The adaptation, palatability, and season for pasturing of the more common of the grasses used for permanent pastures are given in the following table. It is to be noted that Bermuda grass, reed canary grass, red tops, fescue grass, Rhodes grass, carpet grass, and tall oat grass are only medium in palatability. When these are the only grasses in the pasture, the cattle will not eat as much as of the more palatable varieties, and consequently more supplements should be furnished high producing cows. When the pasture consists of a mixture of several grasses, the palatability is increased; and if varieties having optima growths during different parts of the season are used, a pasture of more uniform value throughout the season is secured. A number of legumes adapted to mixed pastures for the different sections add greatly to the value of the pasture.

Legume pastures. All regions of the United States have some legumes that may be used for pasture either alone or mixed with other grasses. The more common legumes with their adaptability, palatability, and season for pasturing are given in the table on page 516. It is to be noted that with the exception of sour clover, all legumes are palatable. Legumes have a distinct advantage in that their nutritive values do not deteriorate with advance in maturity to the extent that those for grasses do. Mature legumes have about three times the digestible protein content and several times as much calcium as mature grasses have. Another advantage of legumes lies in the fact that they make excellent hays. In seasons of rapid growth the acreage used for pasture may be reduced and more cut for hay; and in seasons of poor growing conditions the acreage used for pasture may be expanded.

There are three disadvantages to legumes for pasture. Some of the legumes are likely to produce bloat; most of them are damaged more than the grasses from close grazing; and in the colder climates, they are more likely to winter-kill than the grasses.

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[1] VINALL AND ENLOW. U. S. Dept. Agr. Misc. Pub. 194. 1934.

In some sections the danger of losses from bloat is so great that alfalfa is not pastured. In other sections alfalfa may be pastured without any difficulty from this source being experienced. The Michigan [1] and South

THE REGIONAL ADAPTATION, PALATABILITY, AND SEASON FOR GRAZING OF THE MORE COMMON GRASSES FOR PERMANENT PASTURES [2]

Name	Regional Adaptation	Degree of Palatability	Season for Grazing
Bahia grass (*Paspalum notatum*)	Section 2-b	High	Early spring to late fall
Bermuda grass (*Cynodon dactylon*)	Region 2 and sections 3-b and 4-b	Medium	Late spring to early fall
Brome grass or smooth brome (*Bromus inermis*)	Western part of section 1-a and sections 3-a and 4-a	High	Very early spring to late fall
Canada bluegrass (*Poa compressa*)	Region 1-a and sections 3-a and 4-a	High	Early spring to late fall
Carpet grass (*Axonopus compressus*)	Region 2	Medium	Spring to fall
Centipede grass (*Eremochloa ophiuroides*)	Southern half of region 2	High	Spring to fall
Crested wheat grass (*Agropyron cristatum*)	Sections 3-a and 4-a	High	Very early spring to late fall
Dallis grass (*Paspalum dilatatum*)	Region 2 and sections 3-b, 4-b, and 5-b where irrigated	High	Early spring to late fall
Johnson grass (*Sorghum halepense*)	Region 2 and sections 3-b; also 4-b and 5-b where irrigated	High	Spring to fall
Kentucky bluegrass (*Poa pratensis*)	Region 1 and section 5-a; also 3-a and 4-a where moisture is plentiful	High	Spring to late fall
Meadow fescue (*Festuca elatior*)	Region 1 and section 5-a; also 3-a and 4-a where moisture is plentiful	High	Early spring to late fall
Meadow foxtail (*Alopecurus pratensis*)	Sections 1-a and 5-a; also 4-a at high altitudes	High	Early spring to late fall
Orchard grass (*Dactylis glomerata*)	Region 1; also sections 3-a, 4-a, and 5-a where moisture is plentiful	Medium to high	Early spring to fall
Perennial rye grass (*Lolium perenne*)	Southern half of region 1 and in section 5-a	Medium to high	Early spring to late fall; winter grazing in section 2-a to limited extent
Red top (*Agrostis alba*)	Regions 1, 2, and section 5-a; also under irrigation and in mountain meadows, sections 3-a and 4-a	Medium	Early spring to late fall
Reed canary grass (*Phalaris arundinacea*)	Sections 1-a and 5-a; also 3-a and 4-a where moisture is plentiful	Medium	Spring to fall
Fescue grass (*Bromus catharticus*)	Region 2, and where moisture is sufficient in sections 3-b and 4-b	Medium	Fall to spring (winter pasture)
Rhodes grass (*Chloris gayana*)	Section 2-b; also southern parts of 3-b and 4-b	Medium	Spring to fall
Slender wheat grass (*Agropyron pauciflorum*)	Northern parts of sections 3-a and 4-a	High	Early spring to late fall
Tall oat grass (*Arrhenatherum elatius*)	Sections 1-b and 5-a	Medium	Early spring to late fall
Timothy (*Phleum pratense*)	Region 1 and section 5-a; also 3-a and 4-a where moisture is sufficient	High	Early spring to late fall

[1] DORANCE AND RATHER. Mich. Quart. Bul. 15:30. 1932.
[2] VINAL AND ENLOW. *Op. cit.*

Dakota Stations [1] pastured alfalfa for several seasons and report that no bloat was experienced. Frazer [2] reports unusual milk yields from pasturing alfalfa and that little difficulty was experienced with bloat. Red clovers and sweet clover may also produce bloat under certain conditions. Procedures recommended by the Michigan Station to prevent bloat follow.

1. Keep water and salt available at all times.
2. Give the animals a fill of dry feed before turning them on the alfalfa.

THE REGIONAL ADAPTATION, PALATABILITY, AND SEASON FOR GRAZING OF THE MORE COMMON LEGUMES USED FOR PERMANENT PASTURES [3]

Name	Regional Adaptation	Degree of Palatability	Season for Grazing
Alfalfa (*Medicago sativa*)	All regions where moisture is sufficient, but only locally in region 2	Very high	Spring to early fall. Winter grazing in Southwest when irrigated
Alsike clover (*Trifolium hybridum*)	Chiefly region 1 and section 5-a; in sections 3-a and 4-a if moisture is sufficient; winter crop in region 2	Very high	Early spring and fall
Red clover (*Trifolium pratense*)	*Ditto*	Very high	Early spring to fall
Mammoth red clover (*Trifolium pratense var.*)	Region 1, chiefly section 1-a	High	Early spring to fall
White clover (*Trifolium repens*)	All regions where moisture is sufficient	Very high	Early spring and fall
Ladino clover (*Trifolium repens var.*)	Sections 4-a, 5-a, and 5-b	Very high	Spring to fall
Least hop clover (*Trifolium dubium*)	Sections 2-a and 5-a and parts of section 1-b	High	Spring
Low hop clover (*Trifolium procumbens*)	Section 2-a and southern part of section 1-b	Very high	Spring
Strawberry clover (*Trifolium fragiferum*)	Locally in sections 3-a, 4-a, and 5-a	Very high	Spring to fall
Sour clover or annual melilot (*Melilotus indica*)	Region 2 and sections 3-b, 4-b, and 5-b	Medium	Winter and early spring
Yellow trefoil or black medic (*Medicago lupulina*)	Region 2 and section 1-b	Very high	Early spring to late fall
California bur-clover (*Medicago hispida*)	Sections 3-b, 4-b, and 5-b, if sufficient moisture; also eastern Texas and Oklahoma	High	Fall to spring
Southern bur-clover (*Medicago arabica*)	Region 2 and section 3-b	High	Fall to spring
Common lespedeza (*Lespedeza striata*)	Region 2 and section 1-b	High	Early summer to fall
Korean lespedeza (*Lespedeza stipulacea*)	Section 1-b	High	Early summer to fall
Sweet clover	Region 1	High	Spring to fall

[1] OLSON AND ROBINSON. S. Dak. Bul. 265. 1931.
[2] FRAZER. Hoard's Dairyman 81:56. 1936.
[3] VINAL AND ENLOW. *Op. cit.*

3. Keep the animals on the pasture continuously after once being turned on.

By letting the legumes come into bloom before pasturing the danger from bloat is minimized, but this is not always practical; also, the most valuable time of pasturing is lost.

When legumes, especially alfalfa and sweet clover, are grazed too closely, the stand is greatly injured. It is, therefore, essential that these legumes are not overgrazed.

Supplementary pastures. In most cases the cheapest and most satisfactory supplement to the regular pasture when its productivity is low is some other pasture. Supplementary pastures may be needed in the early spring before the regular pasture gets a good start, during the summer when the regular pasture is unproductive due to heat and drought, and in the late fall.

In the summer and early fall supplementary pasture may be furnished by a number of crops. The second crop of legumes may be used after the first crop has been cut for hay. The first year's seeding of sweet clover has usually attained sufficient growth by summer to furnish good supplemental pasture. High yielding crops making maximum growths during the summer may be specially seeded for pasture. Of these, Sudan grass and soybeans for the North, and cowpeas, Napier grass, and Kudzu for the South, are especially well adapted for temporary grazing. While the grazing for these crops is short, the yields are heavy and only a relatively small acreage is required to furnish adequate pasture during the unproductive period of the regular pasture.

For late fall and early spring the cereal grains—rye, wheat, and oats—furnish excellent pasture. Winter wheat and rye may be pastured during the late fall and winter without any apparent damage to the yield of grain. These crops make their maximum growths during cool weather. During wet weather, annual crops cannot be pastured without serious damage to the crop, due to trampling.

Emergency pastures. Sometimes the stands in the regular pasture are greatly reduced or entirely destroyed because of droughts, winter-killing, or other causes, and it becomes necessary to establish emergency pastures. For the early part of the season the small grains will make the most rapid growth following planting. In the summer and fall the crops discussed under supplementary pastures are satisfactory.

Chapter 45

CHEMICAL CONSTITUENTS OF MILK

MILK IS THE PHYSIOLOGIC SECRETION OF A NORMALLY FUNCTIONING mammary gland. The females of all mammalia normally secrete milk following parturition. The milk from the cow is the most commonly and extensively used for human food. However, milk from the goat, water buffalo, zebu, sheep, llama, camel, mare, and reindeer, and sometimes from still other species, is used in various parts of the world.

Milk is a very complex substance possessing many chemical and physical properties, a knowledge of which is essential to the proper understanding of not only the milk itself, but its many products and the processes involved in its manufacture. The chemical composition of milk is generally considered from the standpoint of groups of chemical compounds. From this standpoint, milk consists of water, fat, nitrogen compounds (proteins), sugar, mineral matter, vitamins, and minor constituents.

General properties of milk. To the casual observer, milk is a fluid varying from a bluish white to a yellowish white color. It is opaque except when in very thin layers. Upon drying it becomes sticky and adhesive. Freshly drawn milk has a sweetish odor that is no doubt due to the gases it contains. It may also have various other odors depending upon the kinds of feed that have been fed.

The taste is slightly sweet. The flavor is largely dependent upon the kind of feed from which it has been produced.

Variations in composition. The chemical composition of milk varies not only with the species but also with the individual, and because of a number of other factors. The factors influencing the quality and quantity of cows' milk are discussed in Chapter 33. While this discussion is chiefly concerned with cows' milk, it is of interest to consider the comparative composition of the milks from several of the different species. In the following table are given what are considered the normal values of the different ingredients of milk from the different species. It is to be noted that the milk from all species contains all the characteristic milk ingredients, but there is a great variation in the proportions of these ingredients. Total solids vary from less than 10 per cent for the mare to 32 per cent for the elephant. Protein varies from 2 per cent in woman's milk to 9.1 per cent in that of the cat. Fat varies from 1.2 per cent in mare's milk to 19.6 per cent in the milk of the elephant. Lactose varies less between the species, from the low for the sow of 3.1 per cent to the high for the elephant of 8.8 per cent.

AVERAGE COMPOSITION OF MILK FROM VARIOUS SPECIES

Species	Total Solids	Protein	Fat	Lactose	Mineral Matter
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
Cow	12.83	3.5	3.8	4.9	.73
Woman	12.6	2.0	3.5	6.8	.30
Goat	13.0	3.7	4.0	4.45	.85
Sheep	17.0	5.2	6.2	4.7	.90
Water buffalo	21.4	5.5	10.5	4.5	.85
Zebu	13.3	3.4	4.2	5.0	.70
Mare	9.6	2.0	1.2	6.0	.40
Llama	13.5	3.9	3.2	5.6	.80
Camel	13.4	3.9	3.0	5.4	.74
Ass	10.36	2.22	1.64	6.0	.50
Cat	18.37	9.1	3.3	4.9	.58
Sow	15.9	7.23	4.6	3.1	1.05
Elephant	32.0	3.1	19.6	8.8	.65

The extreme variation in the composition of cows' milk is set forth in the following table. It is to be noted that the maximum values observed for all the constituents except water are several times the minimum values.

VARIATIONS IN COMPOSITION OF COW'S MILK

Constituent	Maximum	Minimum	Mean
	Per Cent	*Per Cent*	*Per Cent*
Water	90.32	80.32	87.27
Protein	6.40	2.07	3.55
Casein	6.29	1.79	3.02
Albumin	1.44	.25	.53
Fat	10.00	1.20	3.80
Lactose	6.12	2.11	4.9
Ash	1.21	.35	.71

FATS OF MILK

The principal fat of milk is butterfat—one of the most important constituents of milk from the standpoint of commerce, food value of milk, and flavor of milk. In addition to butterfat there are a number of other fats or fatlike substances that play important roles even though they are present in minute quantities. These are phospholipids, cholesterol, carotene, and zanthophyll.

Milk fat. Milk fat or butterfat is a complex mixture. Like most animal fats it is a triglyceride; that is, each molecule of milk fat is made up of one molecule of glycerol to which is bound, chemically, three molecules of fatty acids. It differs from body fat in that it contains many more kinds of fatty acids. Body fats are also made up of fatty acids and glycerol, but they differ from butterfat in that only one, two, or at the most, three different fatty acids are present, while in butterfat there are nine or more fatty acids.

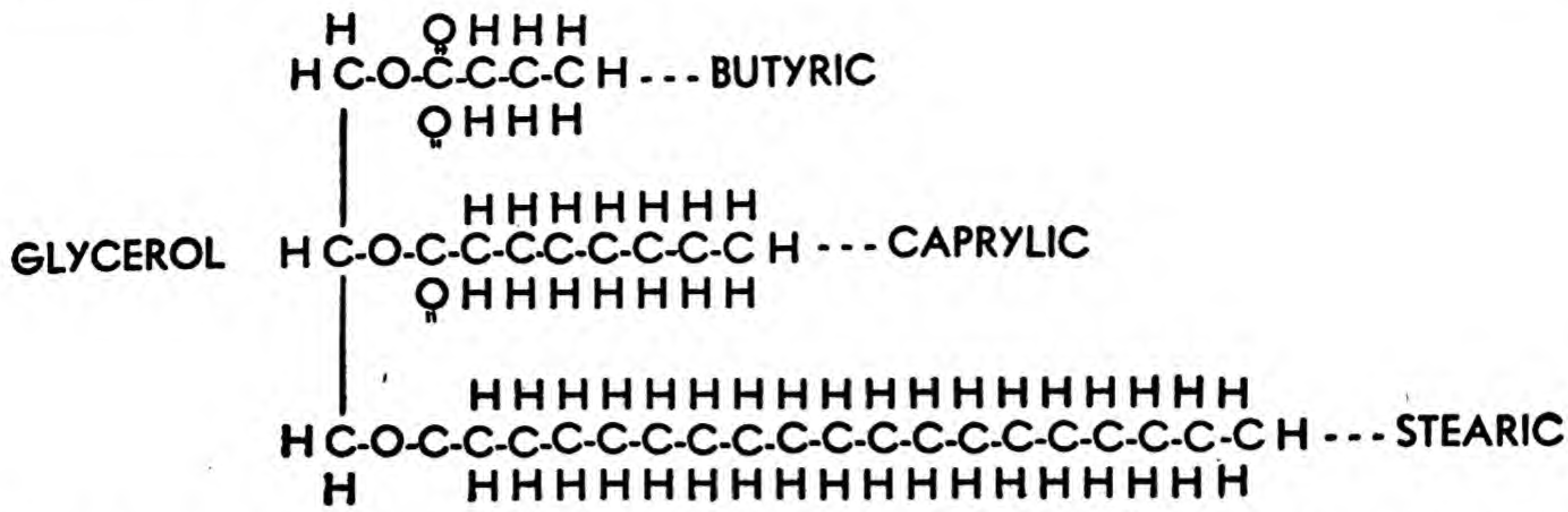

Fig. 113. Configuration of a molecule of butterfat. Mixed triglyceride, containing a butryic, caprylic, and stearic glyceride.

An idea of the structure of a molecule of butterfat is gained from Figure 113. Here is presented the configuration of a mixed triglyceride containing a butyric, caprylic, and stearic acid. They are attached to one molecule of glycerol. As butterfat consists almost entirely of mixed triglycerides and as any difference in the kind of acid or in the arrangement of the same fatty acids in the molecule makes for a change in the character of the fat, it is easy to see that butterfat is a mixture of thousands of different kinds of fat.

The fatty acids. The fatty acids comprise about 94.8 per cent of pure butterfat. They consist of carbon, hydrogen, and oxygen. The oxygen is always constant in that there are always two atoms of oxygen for each molecule of fatty acid. The amount of carbon and hydrogen varies, depending upon the size of the fatty acid molecule and whether it is saturated. The number of carbons in the fatty acid molecules of normal butterfat varies from four in butyric acid to 18 in oleic and stearic acids. From butyric acid each succeeding acid (see the following table) has two more carbons than the preceding acids. Thus, all fatty acids in butterfat have an even number of carbons.

All fatty acids with less than 18 carbons and stearic acid have twice as many hydrogens as carbons. These acids are known as saturated fatty acids. Other acids, known as unsaturated, have two, four, and six less hydrogens than twice the number of carbons. Three of these fatty acids commonly found in butterfat are oleic, linoleic, and linolinic; these contain, respectively, two, four, and six less hydrogens than twice the number of carbons. In these acids the valences of the carbons are satisfied respectively by one, two, and three double bonds between the carbons. These double bonds are of great importance, for it is here that fats are attacked by oxygen to become oxidized and produce the undesirable oxidized flavor.

Each of the fatty acids has characteristics that contribute to the character of the butterfat, and differences in characteristics in butterfat are mainly due to differences in the proportions of the different fatty acids. The melting point of the different fatty acids (see the preceding table) is one of the important characteristics. Butyric, caproic, oleic, linoleic, and linolinic acids have the lowest melting points, and stearic, palmetic, and myristic have the highest.

Fatty Acids of Butterfat, Variations, Average Amounts, and Melting Points

Acid	Number of Carbons	Melting Point °C.	Amounts in Butterfat Range	Average
Butyric	4	−7.9	2.4 to 4.2	2.9
Caproic	6	−9.5	1.3 to 2.4	1.9
Caprylic	8	16.5	.5 to 1.0	.8
Capric	10	31.3	1.2 to 2.0	1.6
Lauric	12	48	4.5 to 7.7	5.8
Myristic	14	58	15.6 to 22.6	19.8
Palmitic	16	64	5.8 to 22.9	15.2
Stearic	18	69.3	7.8 to 20.4	14.9
Oleic	18	14	25.3 to 40.3	32.0
Arachidic	20	77	.0 to 1.0	...
Linoleic	18	−18	? to 6.0	...
Linolinic	18	...	0 to ?	...

The fatty acids do not exist as such in normal butterfat except in very minute quantities. When fatty acids are liberated as such by enzymic or other reactions, a bitter, rancid flavor with corresponding odors is produced. Fatty acids exist, as has been previously stated, in chemical combination with glycerol in what is known as triglycerides.

While the melting point of a glyceride is different from that of the fatty acids it contains, there is a correlation between the melting points of the two. Fats containing relatively large portions of the low melting point fatty acids will also have a low melting point. Tributyric melts at − 69° C. and tri-oleic at − 5° C., while tri-stearic melts at 65° C. and tri-palmetic at 42° C.

The flavor of butterfat is also influenced by its fatty acid content. The lower fatty acids, particularly butyric, contribute to the characteristic flavor of butter. The most characteristic, rancidity of butter, is also due to the presence of free butyric acid.

The average amounts and variations of the most common fatty acids in butterfat are given in the preceding table. It will be noted that butyric, oleic, linoleic, and stearic acids are subject to the greatest variation. Increases in the former three cause the fat to melt at low temperatures and thus become soft, while increases in stearic acid increases the melting point and causes butterfat to be hard. The feeding of flax increases the linoleic, oleic, and linolinic acid content to produce soft butter. The feeding of corn oil and pasture grass increases the oleic acid content to produce soft butter. Cottonseed meal increases oleic acid but also causes a decrease in butyric acid to increase the melting point and produce hard butter.

Classification of fatty acids. Fatty acids are commonly divided into two groups on the basis of volatility; they are the volatile and nonvolatile acids. The volatile acids are butyric, caproic, caprylic, capric, and lauric acids. Of these butyric, caproic, caprylic, and capric are soluble and the others are insoluble. The rest of the fatty acids of butterfat are nonvolatile; of

these myristic, palmetic, arachidic, and stearic are saturated, and oleic, linoleic, and linolinic are unsaturated.

The volatile fatty acids constitute on the average from 15 to 20 per cent of the total fatty acids of butterfat. The nonvolatile group make up 80 to 85 per cent.

Phospholipids. The three phospholipids that milk contains are lecithin, cephalin, and sphingomyelin. Of these milk contains 0.03 to 0.05 per cent of lecithin and but a trace of the other two. The phospholipids contain phosphorus, fatty acids, and glycerol. Lecithin contains two fatty acids and a compound containing phosphoric acid, ethyl alcohol, and trimethylamine. The latter becomes freed under certain conditions to produce a fishy flavor.

Lecithin is concentrated on the surface of the fat globule in milk, and in separation goes almost entirely over to the cream. Skim milk contains but a trace of lecithin. In churning, lecithin is dispersed in the buttermilk and but a trace is normally left in the butter. Buttermilk contains from 0.1 to 0.3 per cent lecithin, depending upon the richness of the cream from which it is produced.

As lecithin is soluble in ether and alcohol it is recovered in fat tests employing these agents. It is also responsible for the difficulty experienced in testing buttermilk by the Badcock methods.

Cholesterol. Milk contains from 100 to 200 parts per million of a complex compound known as cholesterol. This is in solution in the fat and in some of its forms is vitamin D. The vitamin D content of milk may be greatly increased by increasing the vitamin D content of the feed. Whether the cholesterol content of the milk is increased is not known.

Carotinoids. Milk fat contains varying amounts of yellow pigments known as carotinoids. Carotene is the principal yellow pigment of milk fat, although some xanthophyll, the chief pigment of yellow corn, is also present. These pigments are fat soluble and of considerable importance because they are the precursors of vitamin A and give the yellow color to milk. One molecule of carotene forms two molecules of vitamin A, while some of the xanthophylls form but one molecule of vitamin A and others none.

The amount of carotene in milk is dependent upon the quantity in the feed and upon the breed and individuality of the cow. Some breeds and individual cows convert most of the carotene into the colorless vitamin A, while others secrete the carotene into the milk. The Guernsey and Jersey breeds are noted for the latter. Carotene varies from as low as one part up to 20 parts per million of fat.

The carotinoids are synthesized only by plants. Carotene is present in comparatively large quantities in green forage and well cured hays, and is low in grains.

Vitamin A. Butterfat contains varying amounts of vitamin A, a colorless, fat soluble substance. Vitamin A is produced principally from carotene, one molecule of which is split to form two molecules of vitamin A. The amount of Vitamin A in butterfat is dependent upon the amounts

of carotene in the feed and the ability of the cow to convert carotene into vitamin A.

THE PROTEINS

Protein is a complex chemical substance which upon hydrolysis breaks down into amino acids. Protein always contains carbon, hydrogen, oxygen, and nitrogen. Certain proteins also contain sulphur, phosphorus, and calcium. From a nutritional standpoint protein is a most important food stuff. The animal body cannot synthesize protein from anything but protein or amino acids of the food. Certain amino acids can be changed by the animal body to form others needed by the animal. Other amino acids (known as essential amino acids) cannot be formed in the animal body but must be present in the food. The value of a protein is, therefore, limited to the completeness with which it furnishes the essential amino acids.

The milk proteins are excellent sources of the necessary amino acids; they are, therefore, said to have a high biological value. Milk is also rich in protein; it comprises, on the average, 3.55 per cent of the whole milk or about 28 per cent of the dry matter. There are three different proteins in milk. In the order of the quantity present these are calcium caseinate, lactalbumin, and lactoglobulin. There are also traces of other compounds containing nitrogen.

Casein. Casein is a very complex protein containing phosphorus. It is a weak acid and exists in milk as a salt of calcium known as calcium caseinate. Calcium caseinate is not in solution but in a fine (colloidal) suspension which gives milk its white color.

Casein constitutes about 3 per cent of normal milk. It is unique in that it is found no other place in nature but in milk. It may be precipitated out of milk by acids, alcohol, or rennin. The acid precipitate is casein proper, as the calcium is removed in reaction with the acid. Acid precipitation occurs commonly by natural souring; it may also be effected by the addition of acid for commercial casein production. In either case the precipitate is white.

The alcohol precipitate of casein is a calcium caseinate. The rennin precipitate is a new compound, calcium paracaseinate, containing more calcium than the calcium caseinate. Heating at 100° C. for twelve or more hours or at 120° C. for one hour also causes precipitation of casein.

Casein constitutes the bases for cottage cheese and the rennet cheeses. It is also used extensively in the making of glue, for sizing paper, for plastics, and as an adhesive in paints and insecticides. Casein glue is valuable for its adhesive strength and waterproof properties. Casein plastics are hard, take up colors, and can be cut and molded into any desired shape. In addition, it is used for making buttons, combs, billiard balls, and articles resembling marble, ivory, or horn.

Lactalbumin. Milk contains about 0.5 per cent of albumin known as lactalbumin. This protein does not contain phosphorus, but it contains some sulphur, in addition to carbon, hydrogen, oxygen, and nitrogen.

While the molecule is large, it is not so large as that of casein. Lactalbumin is identical with the albumin of the blood in its chemical composition, but it is different structurally.

In milk, albumin is colloidally dispersed. It cannot be precipitated out by acids or rennin and is, therefore, left in the whey from the production of either casein or cheese.

Lactalbumin may be precipitated out of milk by first removing the casein, and then heating the "whey" to 71° C. or above, when a portion of the albumin will come out as a white precipitate. Albumin may also be precipitated with saturated solutions of sodium sulphate and ammonium sulphate and magnesium sulphate in an acid medium.

Lactalbumin has a high biological value and complements casein. While lactalbumin preparations are available, this constituent is not used commercially to any extent. It is an important constituent in milk from the standpoint of its effect upon the stability of the ingredients of milk, and is also important in the processing of milk because of its property of coagulating with heat.

Globulin. Globulin should be classed as one of the minor proteins in milk, as normal milk contains less than 0.1 per cent of this protein. Colostrum milk, however, may contain 10 or more per cent of globulin. Globulin of milk is known as lactoglobulin although it appears to be identical with the globulin of blood in all respects and is probably filtered out of the blood into the milk.

Globulin is in true solution in milk although the molecules are large enough to give the colloidal effect. It is prepared out of the milk by first freeing it from casein and albumin by saturating the milk with sodium chloride, heating it to 35° C., and filtering it, and then saturating the filtrate with magnesium sulphate. Lactalbumin is completely precipitated by heat at 72° C., by saturated magnesium sulphate solution, or by half saturated ammonium sulphate solution. In cheese making, since it is not precipitated by either acid or rennin, it goes into the whey.

Other nitrogen compounds. There are a number of other nitrogen compounds in milk, of which the phospholipids have been mentioned previously. Two other proteins, fibrin and alcohol soluble protein, have been found. The amounts, however, are so small as to be insignificant. Some purine and pyridine bases have also been reported as present in milk in very small amounts. Other nitrogen containing substances present in milk in traces are urea, uric acid, creatin, creatinine, and amino acids. Urea is usually present in the same amounts as in blood.

LACTOSE

Lactose or milk sugar ranks with the proteins and fats as an important constituent in milk. Average milk contains 4.9 per cent of this sugar, which occurs naturally only in milk. It is a disaccharide which yields two sugars, glucose and galactose, upon hydrolysis. Until recently this sugar has not been synthesized.

Lactose is in true solution in milk. It may be crystallized out of milk in

white crystals by first freeing the milk of proteins and condensing it to a small volume. Lactose is about one-fifth as sweet as sucrose, or common sugar. It is less soluble than sucrose, only 17 parts being soluble in 100 parts of cold water, while 200 parts of sucrose may be dissolved in 100 parts of water.

Lactose decomposes in solutions heated at 90° C. for long periods of time to produce a brown coloration and a caramel flavor. This is due to oxidation and reduction in which carbon dioxide and water is given off. Bacteria break lactose down into lactic acid. In this reaction one molecule of lactose should form four molecules of lactic acid.

Other compounds are formed, as only 80 per cent as much lactic acid is produced from bacterial fermentation as would be expected from complete conversion. The bacterial action is self-inhibiting, being completely stopped when 1 per cent of lactic acid is formed. Lactic acid fermentation is responsible for the natural souring of milk and cream, which is of great importance in the dairy industry. Souring of milk, ripening of cream, and production of various cheeses, buttermilk, and so forth are dependent upon lactic acid formation from lactose. Lactose is also broken down by certain yeasts to form alcohol.

MINERAL MATTER

When milk is ashed there remains what is known as ash. This ash constitutes about 0.7 per cent of the milk. The ash must not be confused with the mineral salts in milk, since in ashing the minerals in compounds with organic matter appear as part of the ash. This is particularly true of the phosphorus and calcium in chemical compounds with protein. The minerals in milk are usually expressed as oxides. The approximate amounts of the more common minerals are given in the following table.

APPROXIMATE AMOUNTS OF THE VARIOUS SALT CONSTITUENTS IN THE ASH OF COWS' MILK

Salt	Average Amounts *Per Cent*
Calcium oxide, CaO	.170
Phosphorus pentoxide, P_2O_5	.250
Potassium oxide, K_2O	.170
Sodium oxide, Na_2O	.070
Magnesium oxide, MgO	.025
Chlorine, Cl	.20

It is to be noted that calcium, phosphorus, and magnesium are the most prevalent minerals in milk. In addition to these, iron, copper, iodine, sulphur, manganese, aluminum, zinc, and traces of a number of other minerals such as boron, strontium, and silicon are always present.

Mineral matter in milk is in both true solution and colloidal suspension. A large part of the calcium and phosphorus and all of the sulphur are in chemical compounds with protein. Parts of the calcium and phosphorus

are in colloidal suspension as calcium phosphates. Calcium, magnesium, sodium, potassium, etc. also exist in salts with chlorine, citric acid, CO_3, and PO_4.

Milk has ample amounts of most minerals for the nutrition of growing animals and is especially rich in calcium and phosphorus. It does not have adequate amounts of copper or iron, and under certain conditions is deficient in iodine.

OTHER CONSTITUENTS

Pigments. In addition to the fat soluble carotene and xanthophylls which impart a yellow color to the fat and milk, there is a water soluble pigment known as lactoflavin or riboflavine (formerly lactochrome). This is a yellow or orange colored pigment responsible for the color of whey. Lactoflavin is identical with vitamin G, of which milk is the best source.

Evidence indicates that the lactoflavin content of milk is influenced by both the feed and the cow. Bleached hay produces milk with lower lactoflavin content than does well-cured hay. Pasture grass likewise produces milk with high lactoflavin content. The breeds rank in the following order for the lactoflavin content of milk: Ayrshire, Jersey, Guernsey, and Shorthorn.

Vitamins. Milk is an excellent source of vitamins; it contains all of those now known. These are vitamin A or carotene, vitamin B, vitamin C or ascorbic acid, vitamin D, vitamin E, and vitamin G or lactoflavin. Of these vitamins, B, C, and G are synthesized by the cow, although the amounts of these vitamins in the milk are influenced by the amounts in the feed. Vitamin D may be synthesized by the cow when exposed to the direct rays of the sun or ultraviolet light; otherwise the amount of vitamin D in the milk is dependent upon the amount of this vitamin in the feed. The amount of vitamin A in the milk is entirely dependent upon the amount of the carotene in the feed.

Enzymes. While there is a lack of agreement as to the number of enzymes occurring in milk, it is definitely known that normal milk contains a number of enzymes some of which are important to the dairy industry. Lipase, protease, catalase, peroxidase, diastase, lactase, and reductase have been reported as occurring in normal milk in varying amounts due to various conditions.

Lipase, a fat splitting enzyme, is claimed by some to be present in very small amounts in all milk. It appears frequently in large amounts in the milk of cows that have been milked for a long time. Milk containing this enzyme develops a bitter flavor upon standing unless first heated to destroy the enzyme.

Protease, also known as galactase, is a protein splitting enzyme always present in milk. This enzyme breaks proteins down to simpler compounds and even as far as into amino acids. It is important in the ripening of cheese.

Catalase, which is an oxidizing enzyme, is always present. This enzyme is destroyed when heated from 65 to 70° C. for one-half hour. This fact is

taken advantage of in testing milk for pasteurization, as properly pasteurized milk is negative to the catalase test.

Peroxidase, an enzyme reducing hydrogen peroxide (H_2O_2), freeing active oxygen, is also generally agreed to be a normal constituent of milk. It is, however, of little significance; as it is not destroyed except at higher temperatures, it cannot be used as a test for pasteurization. In separation most of the peroxidase goes into the separator slime.

Diastase, a starch splitting enzyme, is found in the largest amounts in the colostrum milk and in milk from diseased udders. In separation most of the diastase goes into the cream.

Lactase, a lactose splitting enzyme, is not so generally agreed to be a normal constituent of milk.

Reductase, an enzyme causing the oxidation of aldehydes and the reduction of methylene blue, is a normal constituent of milk, and is used as a test for quality of milk.

Gases. Milk contains carbon dioxide when drawn, and it dissolves oxygen and nitrogen together with other gases during milking.

Other compounds. In addition to the constituents so far listed, milk contains varying amounts of other compounds that pass from the blood into the milk. Some of these are discussed under the factors influencing the quantity and quality of cows' milk (Chapter 33). Many flavoring and undoubtedly some nonflavoring constituents of feed pass into the blood from the digestive tract and then into the milk.

Milk also contains varying amounts of white cells and cell debris, and varying amounts of microorganisms that contaminate the udder.

Chapter 46

PHYSICAL AND CHEMICAL PROPERTIES OF MILK

STRUCTURE OF MILK. WHILE MILK IS FLUID IT IS A COMPLEX SYSTEM presenting several phases. There is a continuous phase consisting of water with various materials in solution; there is a colloidal phase consisting of suspended particles of minute size; and there is a coarser suspended phase consisting of particles of microscopic size.

Material in solution. Lactose, most of the salts, and albumin and globulin are said to be in true solution in milk. A true solution is a solution in which the molecules are individually dispersed. In the case of albumin and globulin the molecules are so large that they are also colloidal.

Colloidal material. When the dispersed particles are large enough to be held back by ultrafilters and small enough not to be visible in the microscope, they are said to be colloidal. These particles are said to range from one-millionth to one-ten thousandth of a millimeter in diameter. Calcium caseinate, globulin, albumin, and some of the calcium phosphate are colloidal in milk. These materials may be separated from those in true solution by dialyzing through appropriate membranes. Colloidal particles depend upon certain materials known as stabilizers to keep them suspended. The colloids of milk mutually stabilize one another.

Coarser dispersion. Butterfat is suspended in milk in tiny spherical particles, sometimes called fat globules, to form the chief coarse dispersion in milk. Other particles falling in this category are the cellular constituents of milk, including microorganisms, various white cells, and cell debris. The fat particles vary from .1 micron to ten microns in diameter. The average is three microns. One cubic centimeter will contain from two to four billion fat particles.

Milk fat is not soluble in water; therefore, to stabilize the fat emulsion, each fat particle is surrounded by a material adsorbed on the surface. This material is soluble in water. The material serving this purpose and forming a sort of a membrane around the fat globule consists chiefly of phospholipids and proteins. In churning, these materials are rubbed off and the fat particles coalesce to form butter, while most of the membrane material passes into the buttermilk.

Chemical reaction. Fresh milk is slightly acid in reaction, having a pH of 6.5 to 6.6. If titrated with alkali, with phenolphthalein used as an indicator, fresh milk shows an acidity equivalent to 0.1 to 0.2 per cent of lactic acid. The titration, however, is not due to lactic acid but to the buffers in the milk, including some of the phosphates and proteins.

Fresh milk exhibits the peculiar property of being amphoteric to litmus paper. It will turn blue litmus red, and red litmus blue. Any disturbance

in the mammary gland, such as mastitis, usually affects the *p*H of the milk. As a rule the *p*H increases—that is, the milk becomes more alkaline—although in some cases the change is toward greater acidity. This effect is taken advantage of in testing milk for mastitis.

Specific gravity of milk. The materials in solution in milk have a tendency to increase the specific gravity, while the fat decreases the density. Because there is a great variation in the fat of milk, the specific gravity varies from 1.026 to 1.034, with an average value of 1.032 at 15° C. Skim milk is heavier than whole milk and varies from 1.032 to 1.037.

THE INFLUENCE OF FAT CONTENT UPON SPECIFIC GRAVITY AND WEIGHT PER GALLON [1]

Fat	Specific Gravity at 20° C.	Weight per Gallon at 20° C.
Per Cent		*Pounds*
0.025 (Skim milk)	1.035	8.63
3.0	1.032	8.60
4.0	1.031	8.59
5.0	1.029	8.58
6.0	1.028	8.57
7.0	1.027	8.56
10.0 (Cream)	1.023	8.53
15.0	1.016	8.47
20.0	1.011	8.43
25.0	1.007	8.39
30.0	1.002	8.36
35.0	0.998	8.31
40.0	0.993	8.28

Variations in specific gravities are due to variations in the amounts of the various constituents. Milk fat has a specific gravity of 0.935 to 0.945; milk sugar, 1.67; salts, about 4.0; and proteins, 1.31 to 1.346.

The specific gravity of milk is usually determined by the use of a lactometer which measures the volume of a known weight displaced by the milk. It may also be determined by weighing a known volume.

The effect of varying fat percentages of milk upon the specific gravity is shown in the above table. Specific gravities are used to determine whether milk has been watered. When the fat content of milk is known, the specific gravity may be used in calculating the total solids of the milk. The formula is:

$$\text{Total Solids} = \frac{\text{Sp.g.}}{4} + (1.2 \times \text{per cent fat})$$

Freezing point. Milk freezes at from −0.55 to −0.56° C. (31.01 to 30.99° F.). Skim milk, whole milk, and cream all have the same freezing

[1] From Circular 19, U. S. Bureau of Standards.

point, since the point at which milk freezes is due to the material in solution in the aqueous phase, lactose, and soluble salts. The fat and proteins do not affect the freezing point.

The freezing point of milk is accurately determined by an apparatus known as the cryoscope. The freezing point is changed by the addition of water, salt, or preservative and by the development of acidity. When determined for fresh milk, it offers one of the most reliable tests for watering. Increased acidity, as well as the addition of preservatives, decreases the freezing point and offsets the effect of watering, which increases the freezing point.

While $-0.55°$ C. is the freezing point of milk, it does not mean that milk will freeze solid at this temperature. It merely means that ice crystals will form. When milk freezes, ice crystals will form from the point where the cold strikes, and liquid will be found between the ice crystals and away from the direction in which the cold comes. The ice crystals are of relatively pure water. The solutes are more concentrated in the unfrozen portion. As freezing continues, the unfrozen liquid becomes increasingly concentrated with solutes to still further decrease the freezing point. At $-10°$ C. less than 75 per cent of the milk is frozen.

The addition of 1 per cent of water to milk increases the freezing point by 0.0055° C., or directly proportional to the amount of water added. The formula for calculating the amount of water added to milk from the freezing point is:

$$W = \frac{100\,(\Delta - \Delta_1)}{\Delta}$$

W is the per cent watering, Δ is the normal freezing point of milk, and Δ_1 is the observed freezing point of the sample. Δ should be given the value of $-0.55°$ C.

The freezing point of normal milk is the same as that of the blood. In milk most of the reduction in the freezing point is due to lactose. The amount of lactose in milk will reduce the freezing point by .304° C., leaving .246° C. as that which the other salts present will lower the freezing point. In blood nearly all the lowering of the freezing point is due to the salts.

Boiling point. Because of its solute content, milk also boils at a slightly higher temperature than water. Water boils at 100° C. at sea level, while average milk boils at 100.17° C.

Specific heat. Specific heat is the number of calories required to raise the temperature of one gram of material 1° C. Since water requires 1 calorie to raise it 1° C. (from 15 to 16° C.), the specific heat of a substance expresses the relative amount of heat required in terms of water. The specific heat of dairy products is of great importance in the various processes requiring either cold or heat. Specific heat varies for different temperatures and for different fat percentages. The following table illustrates the

variability in specific heats with varying temperatures for different fat percentages:

Product	At 0° C.	At 15° C.	At 40° C.	At 60° C.
Skim milk	0.940	0.943	0.952	0.963
Whole milk	0.920	0.938	0.930	0.918
15 per cent cream	0.750	0.923	0.899	0.900
30 per cent cream	0.673	0.983	0.852	0.860
60 per cent cream	0.560	1.053	0.721	0.737
Butter	0.512	0.527	0.556	0.580
Butterfat	0.445	0.467	0.500	0.530

It is seen that the specific heat is the highest at 15° C., and that the increase in specific heat at this temperature becomes greater with increases in fat percentage. At other temperatures the specific heat decreases with the increase in fat content.

Viscosity. Viscosity, the resistance to flow, is the reverse of fluidity. Because of its dispersed and dissolved constituents, milk is less fluid or more viscous than water. At 0° C. milk has a fluidity of 0.233, and water has a fluidity of 0.558. At 20° C. these values have changed to 0.473 and 1.00 respectively. Temperature, therefore, markedly affects the viscosity of both milk and water. Viscosity increases with lowering temperatures, and fluidity decreases.

Viscosity also increases with increased fat content, homogenizations, souring, aging, and high heating followed by cooling.

Heating the milk to pasteurization temperatures or agitating it lowers the viscosity.

The viscosity of milk may be measured by the rate a drop will flow down an inclined plate as compared with a drop of water on the same plate. It may also be measured by the rate a given volume will flow through a standard opening, such as a pipette. The most accurate measurement may be obtained by using a viscosimeter, which measures the resistance of the fluid to a moving solid.

Viscosity is of little importance in milk except for its possible relationship to creaming. It is of considerable importance in market cream. Fresh pasteurized cream, which is very fluid, is objected to by the consumer because it appears "thin" and will not whip. By aging, the cream becomes more viscous, appears richer, and will whip more readily.

There may also be some relationship between the viscosity of an ice cream mix and the smoothness of the finished product. Viscosity is also important in the manufacture of condensed and evaporated milks.

Electrical conductivity. Electrical conductivity is due to the solution of electrolytes. Dispersion of material other than electrolytes inhibits conductivity. Milk has both conductive electrolytes and inhibiting nonelectrolytes. Normal milk varies from 180 to 210 ohms in electrical resistance. An increase in fat content or an increase in the amount of protein increases the resistance and decreases the conductivity.

Souring or the addition of salts greatly increases the conductivity. The addition of water decreases conductivity by diluting the electrolytes.

Because so many factors influence the resistance or conductivity of milk, this phenomenon is of little practical value. Some have devised equipment measuring electrical conductance to determine acidity or fat percentage.

Surface tension. Milk possesses a rather high surface tension which decreases with increases in the temperature. Increases in the fat content of milk reduce the surface tension.

Reduced surface tension by the fat in milk helps to stabilize whipped cream and the foam on whole milk and cream.

Cream rising. When whole milk is permitted to stand, the fat rises to the top to eventually form a layer of more or less closely packed fat globules commonly called cream. The difference in the specific gravities of the fat and the milk serum is one of the most important factors responsible for the cream rising. At least for rapid and complete rising of the milk fat, the fat globules must aggregate or clump together. The rate of creaming, then, is largely dependent upon factors that effect clumping of the fat particles.

The rate at which individual particles rise is mostly dependent upon the size, and is proportional to the square of the radius. A particle two micra in diameter was found to rise .05 centimeter per hour; those 3.3 micra in diameter rose .14 centimeter per hour; and those ten micra in diameter rose 1.28 centimeters per hour. Cream rises a great deal more rapidly than the rates given for individual particles; this is accounted for by the clumping of the fat globules into masses containing approximately 50 per cent fat. Troy and Sharp found that the rate at which the fat clumps rise accounts for the rate of cream rising.

The clumping tendency is the greatest in milk cooled rapidly to 7 or 8° C.; this also holds true for cream. This temperature also produces the greatest cream volume, a fact which is explained on the basis that in the piling up of the clumps of fat particles other material is included.

The exact cause for fat particles coming together to form clumps is not known. It is believed that it is something similar to agglutins which forces clumping. The fat particles are held together in the clumps by the mucin-like material surrounding each fat particle. The volume of the cream formed depends upon the thickness of this material and the resultant distance between the fat particles.

The mechanical separation of fat from the milk serum is not dependent upon clumping, but upon increasing the specific gravity about 1,000 times, through centrifugal force. By this large increase in the specific gravity of all the milk constituents, the difference between that of the fat and the serum becomes so great that rapid separation is effected. For small fat particles under one micron in diameter, the difference is not sufficient to bring them out of the milk. These small particles remain in the skim milk.

Foaming. The property of milk that makes it foam when agitated is the cause of considerable annoyance and loss in some dairy processes.

Foam is due to the formation of a physical phase in which air becomes incorporated in the milk, with thin layers of milk separating the air bubbles from one another. The capacity for foaming is due to materials lowering the surface tension. In milk the proteins and the fat reduce the surface tension and, therefore, are the cause of the foaming capacity.

Milk foam is not stable; it breaks down when allowed to stand. Milk fat not only increases the foaming capacity of milk, but also increases the stability of the foams.

Physico-chemical properties of milk fat. *Dispersion.* As has been previously stated, the fat of milk is dispersed as fat globules of various sizes to form a more or less stable emulsion. The emulsion is stabilized by the colloids of the milk and by materials on the surface of the fat globule not present in the aqueous phase of the milk. The latter is represented by phospholipides and other materials which, when combined, are sometimes said to form a membrane around the fat globule.

The fat globules vary greatly in size in the same milk, in milk from different cows, and in milk from the same cow in different stages of lactation. In individual samples of milk the globules will vary from less than one micron up to eleven micra in diameter. Milk from different breeds contains fat globules of the entire range in size, but they differ in the proportionate amounts of the different sizes. The same is true of milks produced in different stages of lactation.

Holsteins and Ayrshires have the smallest average size of fat particles, while Guernseys and Jerseys have the largest average fat particles. The fat globules are the largest at the beginning of the lactation period and decrease in size with advance in lactation. The average diameters are 4.0 micra for Jerseys and Guernseys, and 3 to 3.3 micra for Holsteins and Ayrshires. The mean volume of a fat globule varies for Guernseys from 28.4 cubic microns at the beginning of the lactation to 13.4 cubic micra toward the end of the lactation period. For Holsteins the respective figures are 22.1 and 6 cubic micra.

Physical constants of milk fat. Milk fat at 37.8° C. has a specific gravity of 0.91 to 0.92. Depending upon the type of ration and the stage of lactation, the melting point varies from 27 to 36° C. The melting point is not very definite because milk fat is a mixture of many glycerides possessing different melting points. The refractive index varies from 1.4527 to 1.4566. The melting point and refractive index are used in conjunction with other tests to ascertain whether butter is adulterated. Alone these two tests are of little value.

Chemical constants of milk fat. There are a large number of chemical tests that may be applied to butterfat either to determine variations from normal or adulterations with other fats and oils. The four more common of these constants are:

1. The saponification number, which is the number of milligrams of potassium hydroxide required to saponify 1 gram of fat. The saponification number of butterfat ranges from 220 to 240. The lower fatty

acids cause increased saponification values. Butters adulterated with any fat have low saponification values.

2. The Reichert-Meisl number is a measure of the volatile soluble fatty acids. Milk fat has a larger amount of volatile soluble fatty acids than any other fat, and, therefore, has the highest Reichert-Meisl value.
3. Acid value is the measure of the amount of free fatty acids in the fat. It is expressed as the number of milligrams of potassium hydroxide required to neutralize the acid in 1 gram of fat.
4. The iodine number is a measure of the degree of unsaturation. It is expressed as the number of grams of iodine that are absorbed per 100 grams of fat.

The range in values for the above constants is as follows:

Constant	*Range*
Saponification number	220 to 240
Reichert-Meisl number	20 to 35
Acid value	0 to 0.8
Iodine number	25 to 40

Effect of physical and chemical forces upon milk. When the milk is handled and processed, it is subjected to various physical and chemical forces some of which have a profound effect upon the characteristics of milk. The more common of these forces to which milk is subjected are heat, freezing, agitation, oxidation, enzymic action, chemical treatment, and bacterial action.

Effect of heat upon milk. Milk is subjected to heat in warming up for processing, pasteurizing and condensing, boiling, and higher temperatures under pressure for sterilization.

Warming milk up to 100° F. for separation, clarification, etc. has no effect upon its characteristics except when the temperature is held for long periods of time. A temperature of 100° F. is optimum for microorganism growth. Milk held at this temperature will be subjected to the changes caused by microorganisms.

Heating milk at pasteurization temperatures. Heating milk at 142° F. (61.1° C.) for 30 minutes or at 160 to 180° F. (71 to 82.2° C.) for a few seconds has no appreciable effect upon the characteristics of the milk if it is cooled immediately after heating, except to destroy most microorganisms and some of the enzymes. If the heated milk is held without cooling for some time, the cream layer is greatly reduced. Rapid cooling following pasteurization prevents shrinkage of the cream layer.

When milk is boiled, marked changes take place, many of which are not known. Lactalbumin is coagulated in the same manner as egg albumin is coagulated by heat. The milk takes on a characteristic cooked taste, and a browning of color is effected because of changes in the casein and lactose. Prolonged heating—12 hours of boiling—causes a complete coagulation of the casein. The colloidal calcium phosphate is also precipitated.

If milk is heated under pressure at 130° C., coagulation occurs in one hour. At 150° C. only three minutes are required for coagulation.

When milk is heated in the open, a scum forms over the top. This scum contains all the constituents of the milk. If the scum is removed, a new one begins to form immediately.

Freezing milk. Milk is frequently frozen by exposure to freezing weather or by the use of too cold coils in cooling. One of the chief effects of freezing upon milk is the separation of the fat that occurs when the milk thaws. The casein equilibrium is also affected by freezing. This is shown by the fact that the casein will separate out of milk that has been frozen, if the milk is allowed to stand for a long time.

Cream is frequently frozen for long-time storage. The equilibrium of the fat emulsion is disturbed, for upon thawing some of the fat separates out. The whipping qualities of cream are lowered when it has been frozen. Frozen cream also produces butter of lower quality when churned.

Agitation. In addition to producing foam, agitation has other effects upon the characteristics of both milk and cream. The first and most common effect of ordinary agitation is the separation of the fat through churning. Vigorous agitation such as pumping, especially when the milk is warm, tends to reduce the amount of cream formed, giving what is commonly known as a low or poor cream line.

Vigorous agitation of cream of sufficient fat content incorporates air in fine bubbles, producing whipped cream.

Oxidation. The unsaturated fatty acids and some of the other constituents of milk are subject to oxidation under certain conditions. When the fats become oxidized, a tallowy flavor is produced. This is encountered in milk and cream, and also in butter. Milk from individual cows varies in the susceptibility to oxidation. The feed is one factor that brings about oxidation. The process is speeded up by a number of metals which act as catalysts. Where the tinning is worn off of the equipment with which milk or cream comes in contact, increased oxidation can be expected.

The oxidized flavors in milk are also known as cardboard flavor. It is seldom apparent in fresh milk, but it develops with standing.

Enzyme action. Milk normally contains enzymes which act upon the various ingredients to decompose them. Much (if not all) milk contains lipase, which will split the fat into fatty acids and glycerin. The fatty acids unite with the cations of the milk buffers to form soap, which, in turn, produces the characteristic bitter flavor of such milk. In butter the fatty acids remain as such to produce rancidity.

The proteolytic enzymes will slowly decompose the proteins into peptones and amino acids.

Rennin, not a normal constituent of milk, is added to coagulate the casein into calcium paracaseinate. This is of great importance to the dairy industry as most cheeses are produced from rennin precipitated casein.

Chemical treatment. Milk is subjected to a great number of chemical treatments in various analytical methods, and in neutralizing acid that may have been formed. In testing milk by the Babcock method sulphuric

acid is used to digest or disintegrate all the milk constituents except fat, which is liberated. If a dilute acid is added to produce a *p*H of 4.6, the calcium caseinate is precipitated as casein.

Sour milk or cream may be "sweetened" by the addition of neutralizers such as sodium bicarbonate, calcium carbonate, or magnesium carbonate.

Hydrochloric and citric acids are frequently used to dissolve the milk residue, principally calcium salts, that accumulates on dairy utensils. Milk cans, pails, coolers, pasteurizers, and so forth need to be treated periodically with a dilute acid solution to keep them clean. Citric acid, although more expensive than hydrochloric acid, is safer and more satisfying to use.

Chapter 47

DAIRY MICROBIOLOGY: BACTERIA, YEASTS, AND MOLDS[1]

THE DISCOVERY OF MICROORGANISMS WAS FIRST RECORDED BY ANTHONY van Leeuwenhoek, a Dutch lens maker in Delft, Holland in 1683. However, microbiology—commonly called bacteriology—began with the inspiring and illuminating researches of Pasteur, who gave to science the importance of microbic life. His fundamental researches from 1860 to 1895 laid the foundation for the science of microbiology. He showed the close relationship between bacteria and the biochemical changes occurring in various media. Furthermore, he showed that certain diseases of man, of animals, and of plants were definitely caused by bacteria. Pasteur is generally acclaimed the greatest biologist of all time.

Dairy microbiology is a very specialized branch of dairy science that deals with those microorganisms which are of economic importance to the dairy industry. This important branch of dairy science made its debut in the latter part of the nineteenth century in this country, chiefly through the illuminating researches and writings of Professor Conn at the Storrs, Connecticut, Experiment Station, and of Professor H. L. Russell at the University of Wisconsin. At the present time the importance of dairy microbiology has grown to such proportions that a general knowledge of the action of bacteria is very necessary for anyone intimately associated with the production and processing of milk and the manufacturing of its products. Furthermore, one who has a knowledge of microbiology can give intelligent assistance and co-operation in formulating programs designed for the general welfare of the consumers and the dairy industry from the standpoint of public health.

The bacteria, yeasts, and molds belong to the plant kingdom; they are among the lower forms of plant life, both as to size and morphology. They are frequently referred to as micoorganisms, meaning small, minute, or microscopic bodies.

As found under most conditions, they are not destructive to living protoplasm. Their habitats are many, for they are universally distributed in nature. The upper six inches of soil contain several millions per gram during the growing season. They are present on plants, and are also very abundant in the lower levels of the atmosphere, particularly during the summer months. In fact, micoorganisms are invariably present where there is organic matter. It would be difficult to find a surface exposed to the elements of nature that did not contain some form of microbic life.

DISTINCTIVE CHARACTERISTICS OF MICROORGANISMS

Bacteria. Within the limits of present methods of microscopic examination, bacteria may be defined as unicellular organisms that are

[1] This chapter is contributed by Dr. E. O. Herreid, of the University of Vermont.

devoid of chlorophyll, are in the form of rods, spheres, or spirals, and reproduce by transverse fission.

Size. Bacteria are the smallest of the one-celled plants. Some types are invisible under the highest magnification of the best microscope, while others can be seen under the lower magnifications. The majority of bacteria of importance in the dairy industry fall within the dimensions of 0.5 to 1.0 micron in width and 1 to 2 microns in length. It is estimated by Buchanan [1] that if a bacterial cell had a volume of 1 cubic micron, it would require 1 trillion to have a total volume of 1 milliliter. A micron is equivalent to 0.001 millimeter or about 0.00004 of an inch and is designated by the Greek letter μ.

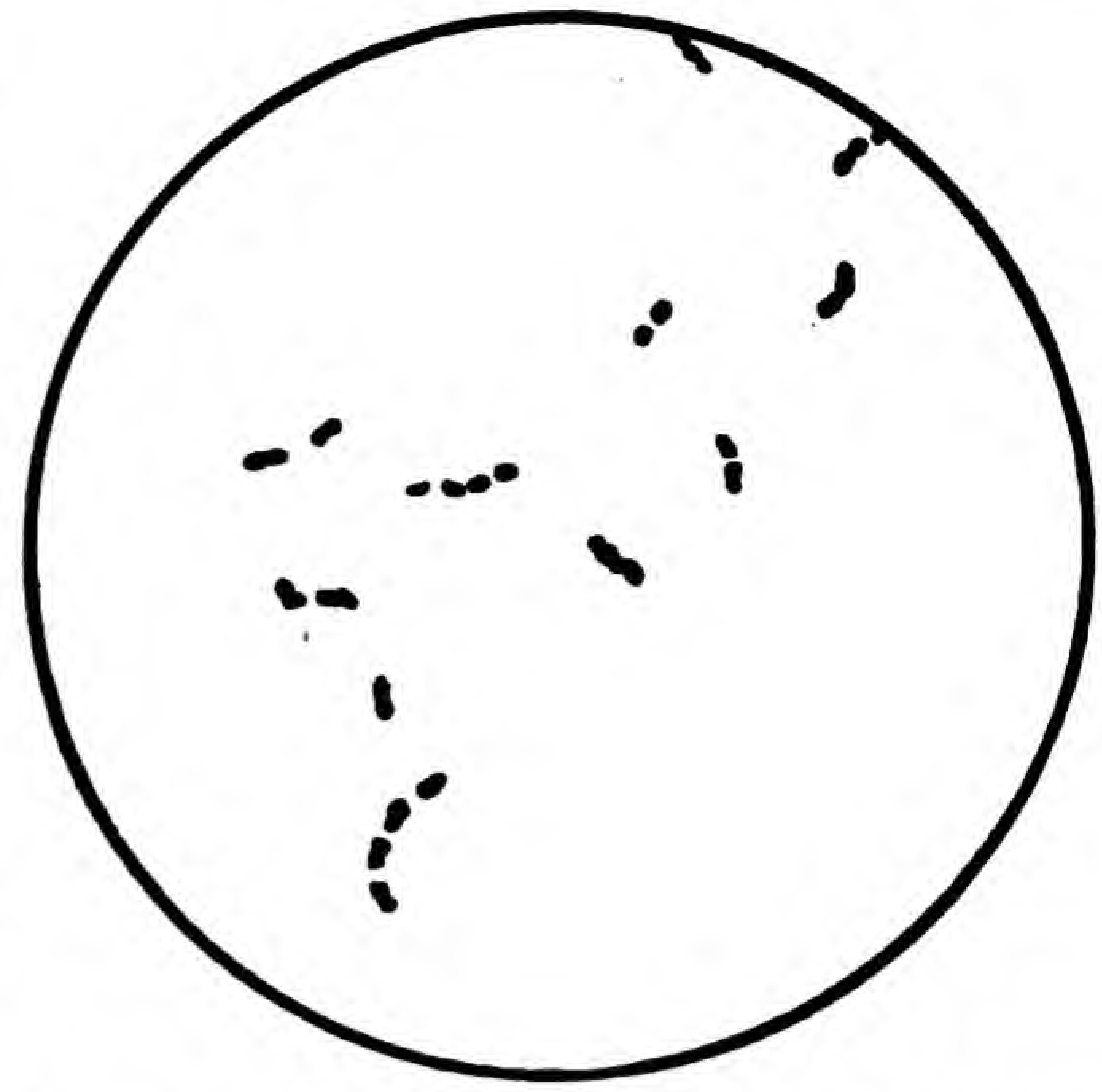

Fig. 114. Showing *Streptococcus lactis,* the common lactic acid producing organism.

The outer cell wall of bacteria is a firm, permeable, and protective membrane through which the soluble food substances diffuse to the interior of the cell. This cell wall may be composed of chitin, or a cellulose-like substance. Inside the cell wall is the ectoplast, a semipermeable membrane that acts as a regulator of substances that may enter and leave the cell. The interior of the cell consists of protoplasmic material, vital to the life processes. As yet no one has demonstrated a nucleus in a bacterial cell. Thus it is evident that each individual cell is equipped to live as an independent entity.

Reproduction. The young bacterial cell normally divides by a process of transverse constriction into two separate daughter cells that grow and elongate. Under favorable conditions cell division in many bacteria occurs about once every half hour. The two daughter cells give rise to four new individuals that in turn give rise to eight new cells—and so forth. Thus bacteria reproduce in geometric progression. If one assumes one division each half hour and reproduction goes on unhindered, the progeny of a single cell would number approximately 140,750,000,000,000 individuals at the end of 24 hours. A population of this magnitude is never approached because the unfavorable environment created by the gradual accumulation of biochemical products eventually checks growth and reproduction and finally results in bacterial destruction. Some bacteria are capable of surrounding themselves with a protective covering enabling them to survive periods unfavorable to growth. These specialized cells, called spores, eventually germinate under favorable environmental conditions. These spores are very resistant to desiccation and heat.

[1] Bacteriology, p. 25. The Macmillan Co., New York. 1931.

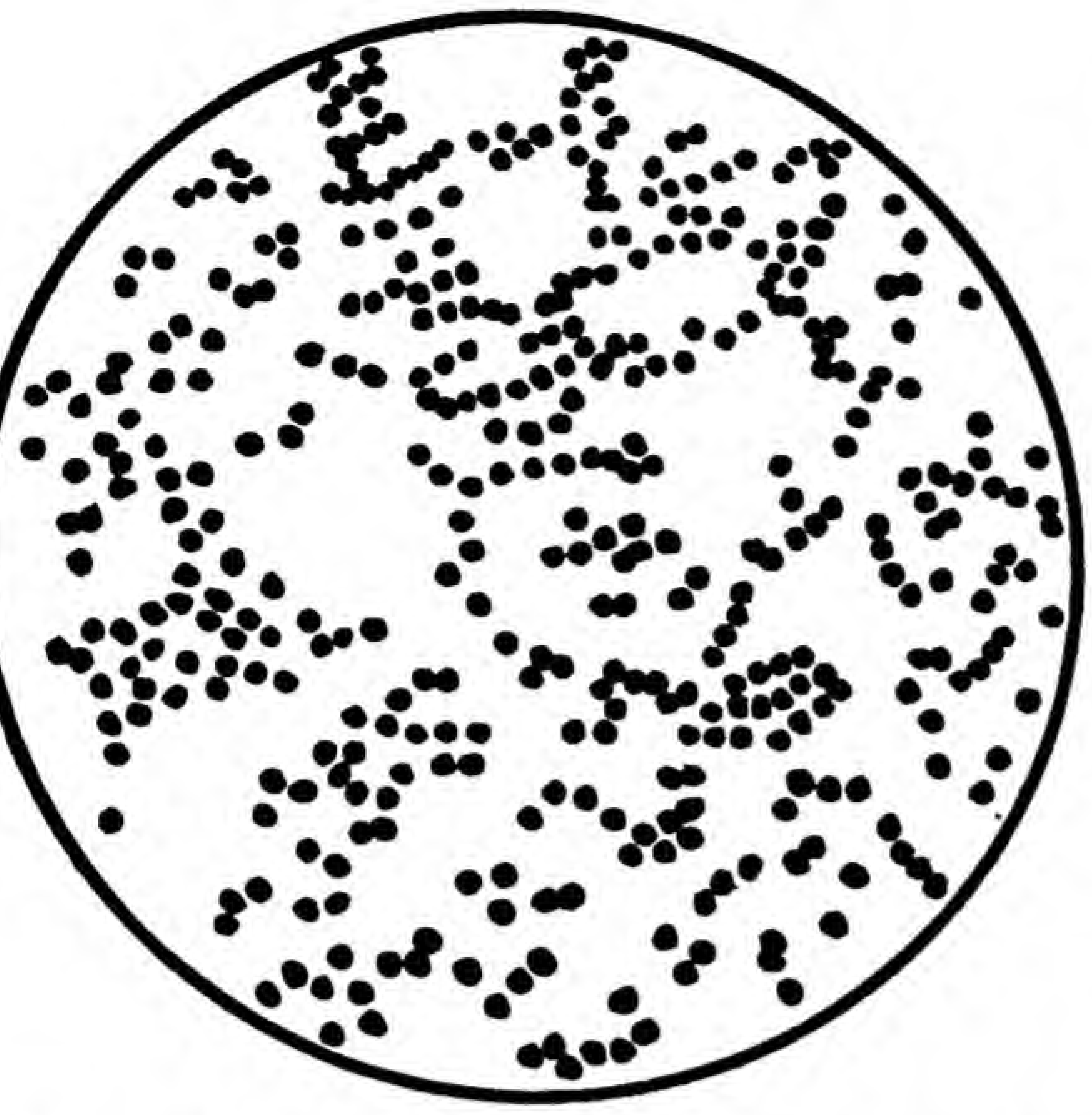

Fig. 115. Showing spherical forms of bacteria.

Morphology. On the basis of their shape, bacteria are divided into three general types. A cell of spherical form is designated a coccus; one that is cylindrical or rod shaped is called a bacillus; one of spiral shape is a spirillum. The spherical and rod forms are of most importance in the dairy industry. Some of the cocci grow singly and some are arranged in pairs. One type frequently found in milk grows in pairs and short chains, and belongs to the genus *Streptococcus.* The rods usually appear singly, but they may under certain conditions appear as filamentous masses due to the sticky gelatinous material at the surface.

Many bacteria are motile and move by means of very delicate appendages called flagella. These flagella may be located at one end of the cell, or in some bacteria several may be located at one or each end, while in other types the flagella may completely surround the cell. These flagella presumably allow the organisms to search for more suitable environments. Bacteria in aqueous solution when seen under the microscope may show rapid oscillatory movements extending over a short radius. This is due to the movement of molecules within the liquid and not due to the presence of bacteria. On the other hand, motile bacteria move across the microscopic field with considerable rapidity.

Yeasts. Yeasts are similar to bacteria in that they are microscopic unicellular organisms devoid of chlorophyll. However, they differ somewhat from bacteria in size, cell structure, and shape. As a rule yeasts are larger than bacteria, having dimensions ranging from 3 to 8 microns in width and from 3 to 80 microns in length. In shape the yeast cell may be ovoidal, ellipsoidal, or circular, depending on the species. A nucleus is present in the cell. Yeasts are widely distributed, and saprophytic and parasitic types are found in nature. Some are of considerable economic importance.

True yeasts reproduce by budding and by the formation of spores. In reproduction by budding there is a bulging and softening of the cell wall that results in the formation of a bud containing some of the cytoplasm and a daughter nucleus. A gradual constriction occurs at the angle of protuberance, resulting in the formation of two daughter cells of unequal size. The small daughter cell matures rapidly and in turn may produce a bud and, thereby, continue the life cycle. Eventually the cells may be separated; however, in some instances they may remain attached to one another.

Spore formation may also occur as a means of reproduction under un-

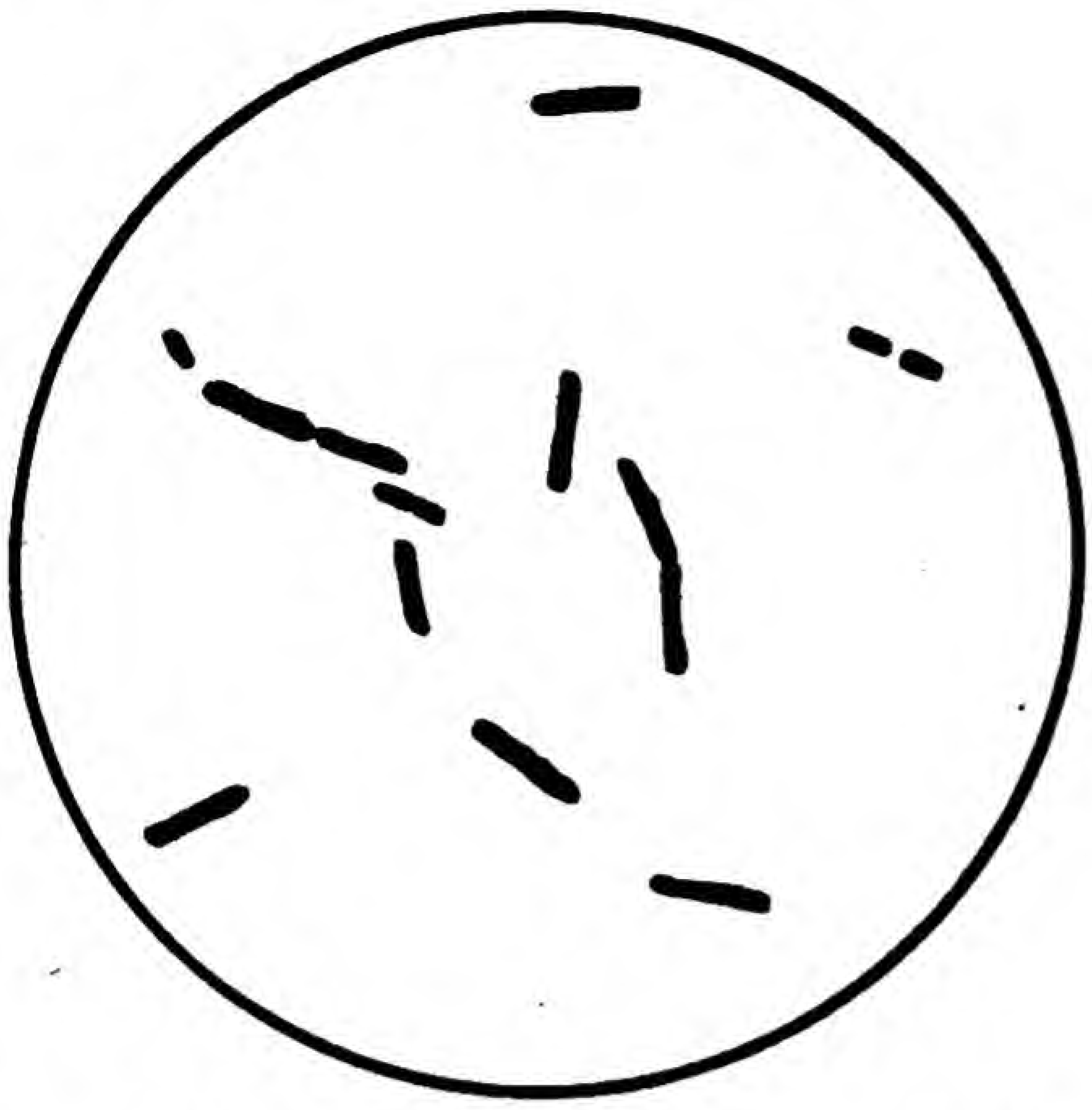

Fig. 116. Showing the characteristic rod forms of some bacteria.

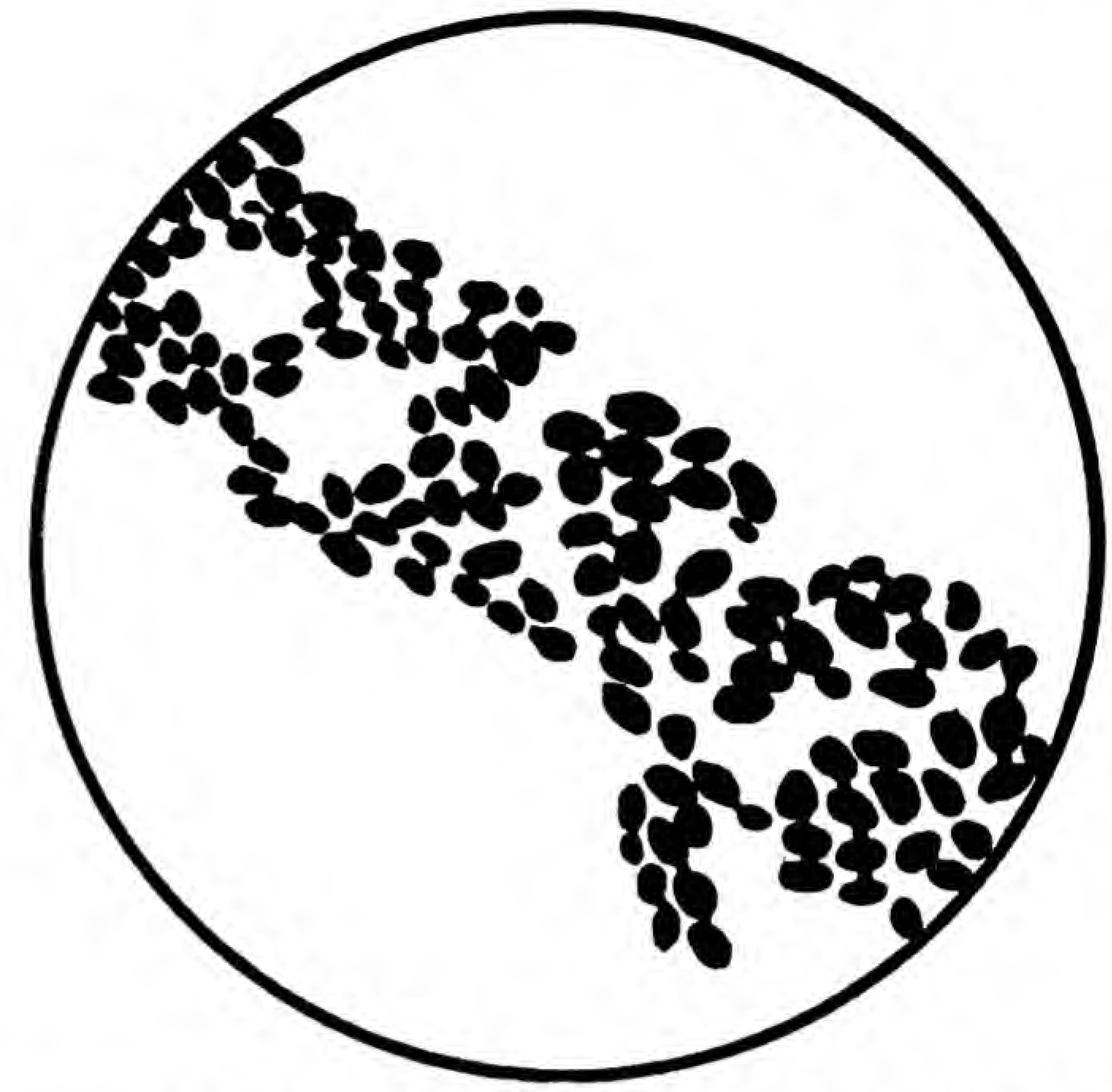

Fig. 117. Showing the oval shape characteristic of yeasts.

favorable environmental conditions. The parent cell serves as a sac to hold the spores, which are usually four in number. With the return of favorable growing conditions, the spore sac absorbs water and bursts, thereby liberating the spores, each of which gives rise to a yeast cell.

The torulae, frequently called false yeasts, are morphologically similar to the true yeasts except that they do not produce spores. Several species are of economic importance to the dairy industry and will be mentioned later in connection with the abnormal fermentations occurring in milk and in cream.

Molds. In contrast to bacteria, molds are multicellular fungi consisting of branching threadlike structures or filaments which are called hyphae. Some of these vegetative hyphae grow on and procure food from the substrate, while some grow upward from the surface and are frequently called fertile hyphae. Most molds reproduce by spores. The fertile hyphae are capable of producing innumerable spores, each of which can continue the life cycle. These spores serve the dual purpose of multiplying and of reproducing the species. Bacterial spores will resist a temperature of 80° C. for 30 minutes, while mold spores are destroyed at temperatures below pasteurization. A number of species are of desirable economic importance and will be referred to in a later discussion concerning the desirable and the undesirable fermentations occurring in milk products.

SOURCES OF MICROORGANISMS IN MILK

One cannot state with any degree of certainty the natural source of the bacteria frequently found in milk. For example, the natural habitat of the common milk souring organism *Streptococcus lactis* has not been established beyond isolating the organism from mangers, feces, the mouth of the cow, and materials about the dairy.[1] The potential sources of

[1] Conn. (Storrs) Agr. Expt. Sta. Bul. 59. 1909.

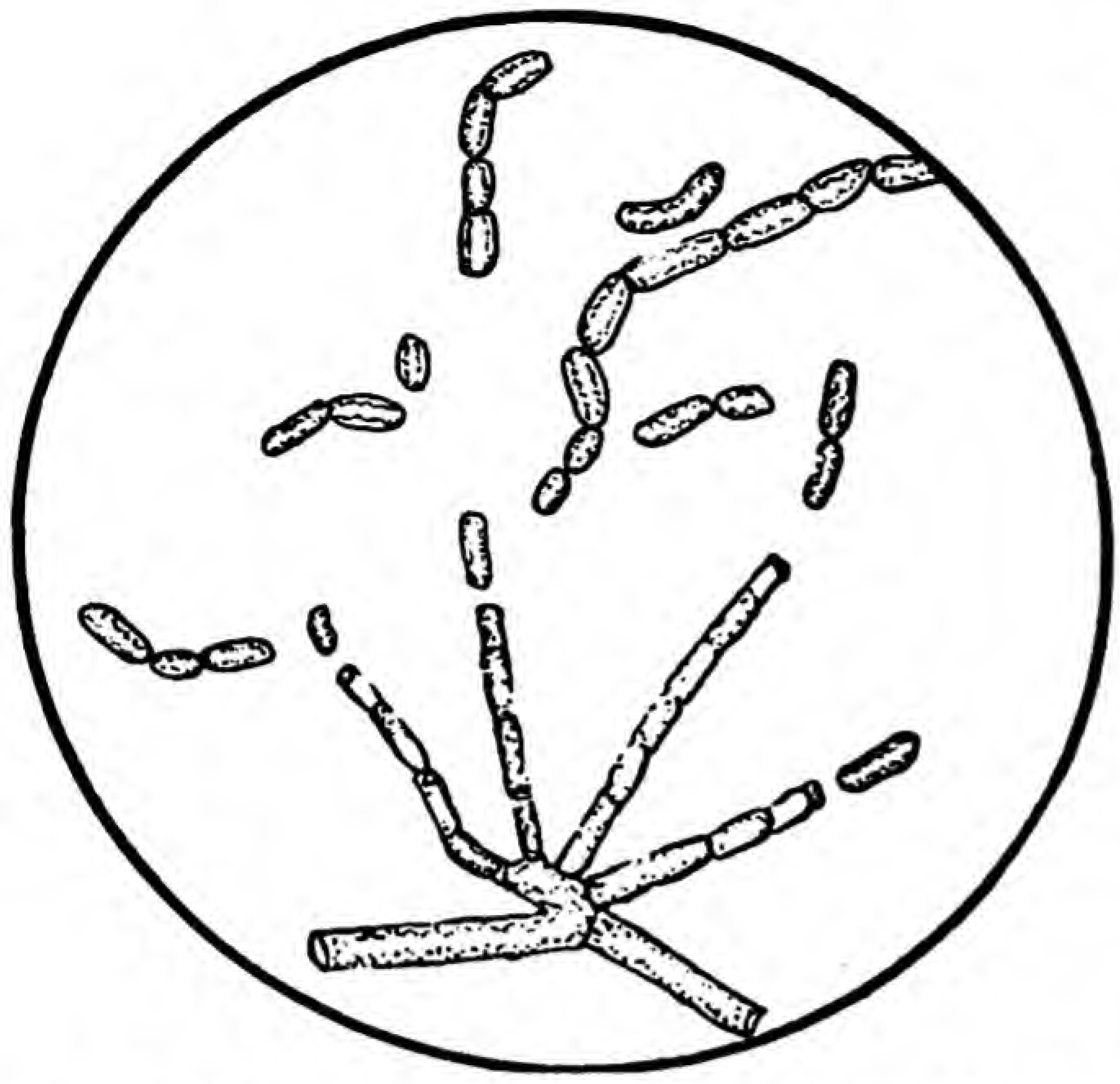

Fig. 118. Showing *Oöspora lactis*, a mold found in milk. The individual cells are called conidia or spores.

bacteria are great because of their universal and natural presence in hays, feeds, ensilage, and the soil. The numbers of bacteria in freshly drawn milk may vary from a few thousand with sanitary methods to several hundred thousand with careless methods of production. The chief sources of bacteria will be discussed.

Equipment. Much experimental work has been accumulated to show that improperly cleaned farm utensils containing remnants of milk solids and free moisture contribute thousands of bacteria per milliliter of milk. Furthermore, the bacteria are actively growing at the time the warm milk comes in contact with the utensils, and the numbers increase rapidly before cooling to 10° C. or lower is accomplished. To accentuate this condition, the flavors and odors formed as a result of the growth and metabolism of bacteria on the surfaces of utensils are carried into the milk and cream. Milking machines and cream separators, if not properly cleaned and sterilized, are prolific sources of bacterial contamination.

The responsibility, however, for the production of milk and cream of low bacterial content does not cease at the farm. To obtain a high-grade product, whether it is fluid milk, butter, cheese, or ice cream, scrupulous sanitation must be practiced through the processing and the manufacturing operations. This means that pasteurizers, pumps, coolers, cheese, butter and ice cream equipment, churns, and other equipment must be kept clean and practically sterile. This can be accomplished on the farms and in the dairy plants by rinsing the metal surfaces with cold water and removing most of the milk solids, brushing the surfaces with a hot alkaline washing powder solution, rinsing them twice with cold water, and practically sterilizing them in the flowing steam for five minutes. This will destroy almost all the vegetative forms of bacteria; the spores, which are usually insignificant as far as numbers are concerned, are left on the cleaned equipment. The hot utensils will drain and dry rapidly, leaving no free moisture. This treatment does not apply to churns.

The types of bacteria found ordinarily on unsterilized utensils on the farm and in milk plants are chiefly acid producers. However, in the case of unclean churns, other objectionable types, together with molds and yeasts, have been found in abundance.

Exterior of cow. The cow's covering presents abundant surface for adsorbing foreign material. Commonly such adhering debris consists of soil, feces, and general filth about the stable containing large numbers of undesirable bacteria, chiefly the gas producing and putrefactive types.

Prucha and associates [1] reported that fresh feces contained 8,486,000 bacteria per gram of dry matter. Obviously only small amounts of fecal material will increase the bacterial content of milk, and the organisms will be those that are most detrimental to the quality of milk and milk products. This source of contamination can be practically eliminated by keeping the udder and the flanks clipped closely, and then washing these parts and drying them with a clean cloth before each milking. The use of the small-top pail will prevent much extraneous matter from dropping into the milk.

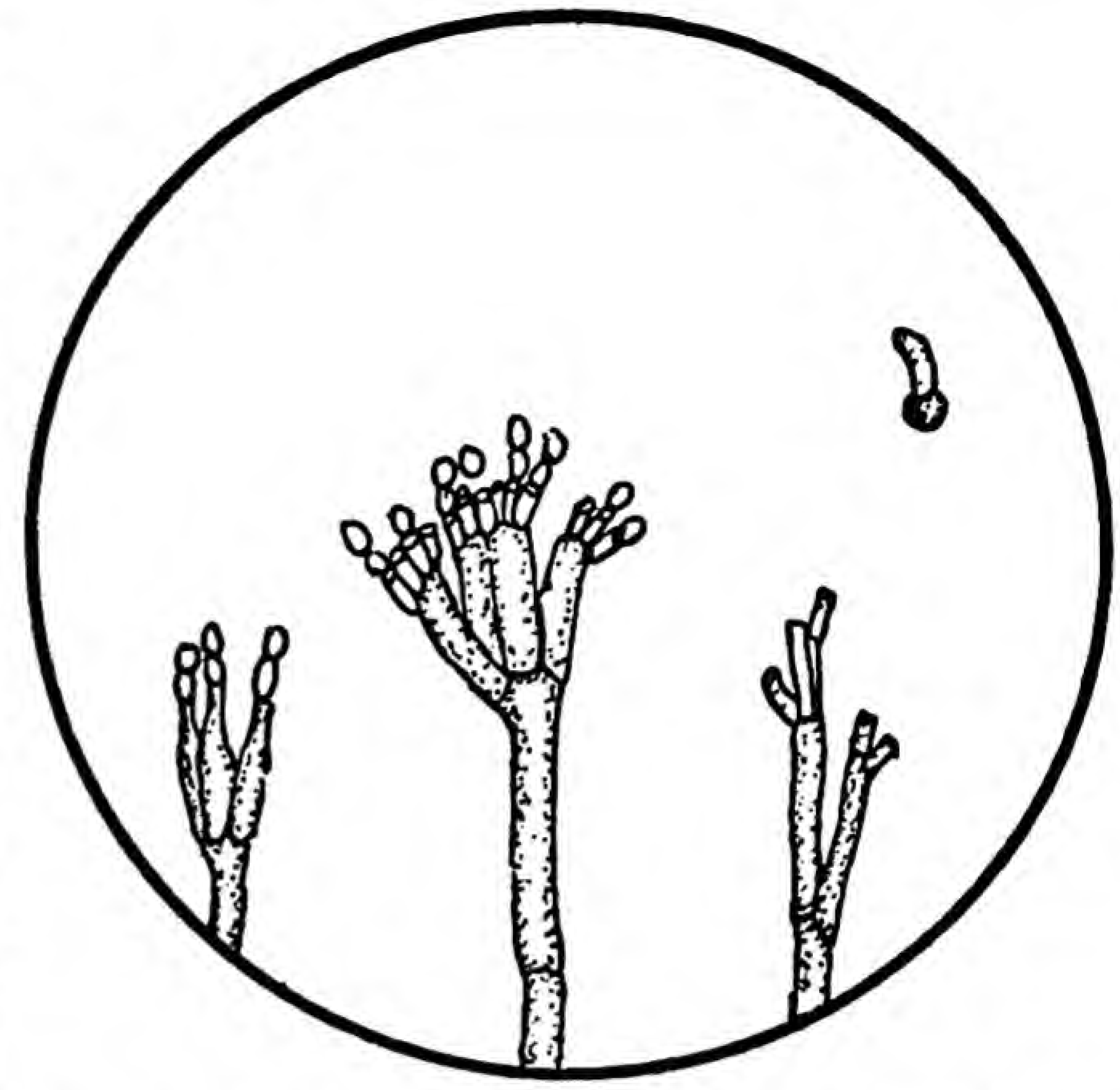

Fig. 119. Showing *Penicillium roqueforti,* the mold prominent in the ripening of Roquefort cheese. Fertile hyphae.

Interior of udder. Lister's [2] misinterpretation of his experiments in 1878 established an opinion of long standing that freshly drawn milk as it comes from the udder is free from bacteria. He concluded that the bacterial growth in practically 96 per cent of the samples of aseptically drawn milk was due to bacterial contamination from outside the udder. However, in 1899, Moore [3] at Cornell University proved that milk as it comes from the udder does contain bacteria. Ward [4] concluded that milk was sterile at the time of actual secretion, but became contaminated in the small ductlets and in the milk cistern. Small, round bacteria (*micrococci*) appear to be the most prominent group of organisms normally found in aseptically drawn milk. They are inert and produce no important changes in milk. The total number of bacteria is aseptic milk from healthy cows varies from a few hundred to thousands per milliliter. Frequently individuals in a herd have such inherently high bacterial content that the herd milk cannot comply with the rigid standards required for the production of certified milk, in which the count usually must not exceed 10,000 bacteria per milliliter. In instances such as this, the milk from cows having excessive numbers of bacteria must be excluded from the regular supply.

Feeds. Since bacteria are found on vegetation and in the soil, they are abundant on most grains and roughages. It is evident that there is ample opportunity for bacterial contamination to occur in milk from feeds and litter about the stable, particularly if there is carelessness in feeding practices. The feeding of excessively dusty and moldy feeds should be avoided if it is humanly and economically possible. It is preferable to feed after milking or at a sufficient time prior to milking so that the dust

[1] Abs. Bact. 2, p. 6. 1918.
[2] Rogers and Associates. Fundamentals of Dairy Science. 2nd ed., p. 404. Reinbold Pub. Co. 1935.
[3] Proc. Soc. Prom. Agr. Sci., p. 110. 1899.
[4] N. Y. (Cornell) Agr. Expt. Sta. Bul. 178. 1900.

has subsided. It has been shown that the atmosphere in a ventilated barn is not a serious source of bacterial contamination under carefully managed conditions.

Stable. It has been shown that the stable is not directly responsible for the large numbers of bacteria in milk. Indirectly, however, the stable is an important factor. Adequate light and ventilation contribute to the health of the animals. In addition, milk obtained in a well-ventilated stable is not so likely to absorb the flavors and aromas associated with the barn during the winter months. The ceilings should be tight to prevent dust and dirt falling from haylofts, and the general construction should be such as to discourage the accumulation of dirt. The esthetic features of a dairy barn are important factors in encouraging the employment of strict sanitation.

Water supplies. A bacteriologically pure water supply is of vital importance on the farm and in the dairy plant. Badly polluted water invariably harbors the types of bacteria most detrimental to the keeping quality of milk and milk products and to public health. Impure water results in general contamination, so that equipment used in handling milk or cream on the farm and in the dairy plants frequently becomes infected with spore-formers that are not destroyed by pasteurization. Infected water supplies have been the cause of serious economic losses in creameries.

Attendants. The successful operation of a dairy farm or a dairy plant requires a knowledge of the factors concerned with sanitation, and their intelligent application. The production of clean milk and the manufacture of fine quality milk products is not difficult. It merely implies some initiative, ambition, and interest on the farms and in the dairy plants in applying a few fundamentals that yield desirable results. The dairy industry should not tolerate irresponsible personnel who, through carelessness and negligence, do not appreciate in every aspect the fundamental factors of sanitation. The good effects of any quality program are largely nullified if dairymen on the farms and plant workers fail to do their part. Most of the important milk producing areas have rigid systems of inspection on the farms and in the dairy plants. Those not complying with sanitary specifications are penalized by a lower price or by the product being refused at the plants.

The dairy industry in all its ramifications should employ persons of the highest type of intelligence and training, thus insuring the safeguarding of quality to the point where consumers will have the utmost confidence in milk and milk products.

CHEMICAL-PHYSICAL REQUIREMENTS OF MICROORGANISMS

Micoorganisms do not have chlorophyll, and therefore they cannot utilize radiant energy from the sun to synthesize compounds for energy and for growth.

Food supply. Bacteria must have sources of food that will supply energy for growth and development. Most of the bacteria, yeasts, and

molds secure such energy by the oxidation of organic and inorganic compounds.

The food substances utilized by micoorganisms must be in simple and soluble form before assimilation by the organism can take place. Most of the constituents of milk are too complex to be used immediately by microorganisms. Consequently, the organisms must partially decompose the proteins, the fats, and the sugars into simpler compounds before they can be utilized for energy, for maintenance, and for growth. This is accomplished chiefly through the action of enzymes secreted by the bacterial cell. The enzyme may be defined as an organic catalyst capable of inducing a biochemical reaction without becoming a part of the final products of the reaction. It is not definitely known how many different kinds of enzymes are secreted by bacteria. Some may secrete one or several different enzymes capable of producing different chemical products. The reactions are chiefly hydrolytic and oxidative. For example, an enzyme capable of hydrolyzing proteins is given the general name of a protease. One hydrolyzing fat belongs to the general group of lipases. One of the oxidizing enzymes frequently alluded to in dairy literature, called catalase, is secreted by a great number of bacteria. The outstanding characteristic of an enzyme is the infinitesimally small amount that is capable of bringing about profound chemical changes in the substances acted upon.

Milk contains all the substances necessary for the growth and development of most bacteria of economic importance to the dairy industry. Therefore, the nutritional requirements of bacteria will be correlated with the constituents of milk products.

Bacteria require a source of carbon, and in milk and milk products lactose is the most readily available source. However, before lactose, a disaccharide, can be utilized by bacteria, it must be split by the enzyme, lactase, into its constituent sugars, glucose and galactose. Of the two, glucose is most readily fermented to simpler compounds, such as lactic acid, alcohol, and carbon dioxide. It is believed that the resistance of galactose to fermentation is due to the different molecular structure as compared to glucose. Under certain conditions bacteria may get their carbon from the proteins.

The butterfat of milk consists of a mixture of triglycerides that under certain conditions might serve as a source of carbon or energy for bacteria. A number of species of bacteria will induce hydrolytic reactions in butterfat through the action of lipase-like enzymes, and will liberate free fatty acids and glycerol. Rancid butter is a typical example of this biochemical reaction.

Bacteria that grow and produce biochemical changes in milk utilize nitrogen. Casein, lactalbumin, and lactoglobulin are the principle nitrogenous compounds in milk in addition to the phospholipids. The degree of decomposition of these milk proteins by bacteria varies greatly, depending on the types of bacteria. If the nitrogen demands of an organism are considerable, it is evident that such complex molecular structures as the proteins of milk must undergo radical chemical changes through the

activity of enzymes before the simpler nitrogen compounds such as amino acids and proteoses are available for absorption by the bacterial cell. When protein cleavage has reached this stage, milk and cream usually are unfit for human consumption or for manufacturing purposes. However, Kieferle and Gloetzl [1] have shown that milk does contain, in addition to the proteins mentioned, a variety of nitrogenous substances, such as urea, amino nitrogen, creatin, creatinin, and uric acid, that may serve as a source of nitrogen. The quantity of these compounds in milk is small, yet the amounts may be sufficient as a sole source of nitrogen for those bacteria unable to utilize the more complex proteins. Most of the bacteria of economic importance to the dairy industry have been shown to exhibit varying degrees of ability to decompose proteins.

Oxygen. The oxygen requirements of micoorganisms found in milk and milk products vary within rather wide limits, and they may, therefore, be conveniently divided into four general groups. Those that require free oxygen are called aerobic, while those that will not tolerate free oxygen are called anaerobic. The anaerobic bacteria, however, require the presence of certain compounds that can be reduced, and make use of the oxygen thus liberated. A third grouping includes the facultative bacteria, which are able to grow under either aerobic or anaerobic conditions. A fourth group includes bacteria that will not grow under atmospheric conditions, but require small but definite quantities of oxygen; these are called microaerophilic. The typical lactic acid producing bacteria belong to the facultative group. At the other extreme are the molds frequently seen growing on exposed surfaces containing organic matter; these require free oxygen. The true yeasts and the torula of importance in dairying are able to thrive between the extremes of the absence and the presence of free oxygen.

Moisture. Water is indispensable for the growth and metabolism of bacteria, yeasts, and molds. Bacteria and yeasts grow best in an aqueous solution such as milk. According to Buchanan and Fulmer [2] bacteria contain from 70 to 90 per cent water. If the medium in which the organism is growing does not contain adequate moisture, growth will be retarded due to a disturbance of the water equilibrium in the bacterial cell. Milk and cream contain adequate water for bacterial growth. Although butter contains at the most 16 per cent water which, because butterfat and water do not form molecular solutions, is distributed in the form of fine droplets, unsalted butter may contain several millions of bacteria per milliliter. In salted butter the numbers are not so great because of the retarding effect of the salt. The different varieties of cheese contain varying amounts of salt, and from 30 to 40 per cent moisture that adequately maintains the growth of the microflora concerned in ripening. On the other hand, the different kinds of dried milk powder do not support bacterial growth because the moisture content of 3 to 5 per cent is far

[1] Milchw. Forsch. 11:63–117. 1930.
[2] Physiology and Biochemistry of Bacteria. Vol. 1, p. 68. Williams and Wilkins Co., New York. 1928.

below the optimum required. Most molds grow best in a humid atmosphere that is near the point of saturation; in fact, it is a common observation to see them growing on the exposed surfaces of foods stored in damp places.

Temperature is one of the very important factors affecting the growth of bacteria in milk and milk products containing otherwise adequate moisture and available nutriment. The growth and metabolism of bacteria is a biochemical process that is difficult to express in a quantitative reaction. As a rule the rate of a chemical reaction is approximately doubled for each rise in temperature of 10° C. Such a change in temperature can influence greatly the kind of products elaborated by a bacterial cell from what might be produced under other temperature conditions. For example, in the manufacture of the popular American Cheddar cheese the temperature during the manufacturing process must be carefully controlled; furthermore, the cheese must be ripened at the proper temperature in order to obtain the desired flavor and aroma so characteristic of this cheese. In the manufacturing process of a highly flavored butter special cultures are employed to develop a fine flavor and aroma in the finished product. In order to accomplish this, the cream must be held at a temperature of 21 to 22° C. for 10 to 12 hours to undergo what is commonly called ripening. Any marked deviation from this temperature will not give the desired results.

In general, micoorganisms grow over a wide range of temperatures. By far the greatest number of species of importance to the dairy industry grow within the range of 5 to 45° C. The growth is slow for most types at both extremes. The optimum temperature employed for the common lactic acid producing bacteria is in the region of 20 to 22.2° C.; they will grow rapidly at temperatures of 27 to 38.8° C., but these higher temperatures also stimulate the growth of bacteria that produce biochemical substances detrimental to the quality of milk and milk products.

A group of bacteria frequently encountered in the dairy industry grow at temperatures above 50° C. These are called thermophilic (heat-loving). These thermophilic types are found in the surface of the soil, in decaying manures, and in silage. Since they are widely distributed in nature, they are usually found in raw and in pasteurized milk. According to Rogers and associates [1] some of the true thermophilict ypes survive temperatures of 62.5 to 65.5° C. and may also grow and multiply between 30 and 65.6° C. Some of the heat-loving types do not grow, but may survive ordinary pasteurization temperatures; they are called thermoduric types.

A few species of bacteria grow at temperatures below 5.0° C.; these are called the psychrophilic or cold-loving types. These micoorganisms are found chiefly in cold water sources, such as wells. Certain of the water bacteria are very detrimental to the quality of milk products as they cause undesirable fermentations. Furthermore, these water bacteria grow at temperatures that retard other types.

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[1] ROGERS AND ASSOCIATES. *Op. cit.*

Osmotic pressure. The effect of osmotic pressure on bacteria is of importance in dairying. By definition this is the force created when two solutions of unequal concentration and separated from each other by a semipermeable membrane seek an equalization of the substances in solution. The semipermeable membrane in the bacterial cell is the ectoplast lying just within the outer cell wall and surrounding the protoplasm. In this respect sweetened condensed milk is an illustration of a product having a relatively high osmotic pressure due to the sucrose concentration of 40 to 42 per cent. Bacteria do not, as a rule, grow in this product. This is due to the fact that the concentration of the constituents in the bacterial cell are lower than that of the sweetened milk, resulting in the passage of water from the cell into the condensed milk until the concentration inside and outside the cell is equal. The cell loses water, and thus its growth is retarded or actually inhibited. Bacteria vary in their sensitivity to osmotic pressure, and certain species may gradually become acclimated to increased pressures. On the other hand, it is equally possible that the growth and metabolism of bacteria in a medium may result in the gradual accumulation of products that increase the osmotic pressure to an intolerable point, resulting in the death of the cells.

Hydrogen ion activity. As bacteria grow in milk and milk products, they gradually change their environment. These changes may be manifested in several ways. If such changes are accompanied by acid development, ultimately a point is reached where the accumulation of dissociated acids and active hydrogen ions, or an increase of undissociated acids, or both, may limit the growth of bacteria. As an example, the common lactic acid producing bacteria will not usually produce an acidity in the milk to exceed 1 per cent calculated as lactic acid. Furthermore, changes in alkalinity may be equally disastrous to bacterial life.

METHODS OF ESTIMATING MICROORGANISMS

There are a number of methods employed to estimate the numbers of bacteria in milk and its products. Two common procedures will be described for milk. Both may be modified for other dairy products.

Breed's method, or the direct microscopic count. In this method 0.01 of a milliliter of milk is spread over an area of 1 square centimeter and allowed to air dry. This thin film is stained with a dye, coloring the bacteria so that they may be clearly seen with the aid of a microscope. The microscope is so calibrated that approximately 1/3,000 part of a square centimeter is visible in each field; or, stated another way, each square centimeter has about 3,000 microscopic fields. Due to the fact that only 0.01 of a milliliter of milk is used, each microscopic field is equivalent to 1/300,000 (3,000 × 100) part of a milliliter. Each organism found, therefore, represents 300,000 bacteria per milliliter of milk. For example, if an examination of 30 fields shows an average of 10 bacteria, this would mean a total count of 3,000,000 (300,000 × 10) per milliliter.

The agar plate count. This method, which may be used for bacteria, yeasts, and molds, consists of adding milk in varying quantities to Petri

plates, followed by a liquid nutrient medium that solidifies at 38 to 40° C. and supports the growth of microorganisms. The assumption is that each bacterial cell will germinate and give rise to a visible cluster of bacteria called a colony. These Petri plates have an internal area of 65–66 square centimeters. If 1 milliliter of milk containing about 10,000 bacteria were placed in the plate and most of them were to grow, the plate would be so crowded with colonies that an accurate estimation would be impossible. For this reason it is usually necessary to start with a dilution of 1 milliliter of milk in 99 milliliters of sterile water, making a concentration of 1–100. Taking 1 milliliter of this dilution (1–100) in 99 of water, a concentration of 1–1,000 is obtained. If 15 colonies develop on the plate with a dilution of 1–1,000, the count will be 15 × 1,000, or 15,000 bacteria per milliliter or gram, depending on the product and the unit used. Not all the bacteria in raw milk grow on this standard medium; consequently the microscopic count is almost always higher than the plate count.

The microscopic and plate count methods have their individual advantages and limitations that are not within the scope of this discussion. It is sufficient to state that both have proved valuable for estimating the numbers and types of microorganisms in milk and its products, with ultimate application to the improvement of quality.

BIOCHEMICAL CHANGES IN MILK PRODUCTS

Desirable Fermentations

Some of the desirable fermentations occurring in milk have been discovered more or less accidentally and have been put to practical use. In so far as it is possible, these fermentations in milk and its products are carefully supervised, from the laboratory on through the processing and manufacturing operations. In the following discussion the organisms associated with specific fermentations will be cited whenever possible. These names may appear unwieldy, but international agreement has resulted in the adoption of Latin as the common language for naming microorganisms. The first name, a proper noun, is the genus; the second is the species.

Butter cultures. Butter cultures or starters are of importance because of their ability to impart desirable flavors and aromas to milk, cream, butter, and certain varieties of cheese. Butter cultures are carried in milk and consist of *Streptococcus lactis* and associated citric acid fermenting streptococci that are called *Streptococcus citrovorous* and *Streptococcus paracitrovorous*. One or the other of the associative organisms must be present in a butter culture to obtain the desired flavors. The characteristic flavor and aroma of butter cultures are due to the associative acidity of *S. lactis* and the citric acid fermenting streptococci. The biochemical products formed are lactic, acetic, and proponic acids, and diacetyl from acetylmethylcarbinol. The optimum temperature for butter cultures is

from 21 to 22° C., and the time required to produce the desired flavor and aroma varies from 12 to 16 hours. Butter cultures, when allowed to grow in cream, develop their characteristic flavors and aromas that are incorporated in the butter during the process of churning. Dr. B. W. Hammer and associates at Iowa State College have made the most important contributions to the microbiology and the biochemistry of butter cultures in this country.

Cheese making. The production of ripened cheeses is entirely dependent upon microorganisms for the changes that take place in the ripening process and in preparing the milk for cheese making. (For more details on cheese making see Chapter 52.) In Cheddar cheese production, *S. lactis* first develops the necessary acidity of the milk and cheese then dies, and *Lactobacillus casei* next act upon the proteins to break them down into simpler compounds. In the making of Roquefort types of cheese, *S. lactis* is depended upon to bring about the proper acidity, and then the mold *Penicillium roqueforti* is added to bring about the breakdown of proteins and fats. In the production of Swiss cheese, *Streptococcus thermophilus* plays an important part because it survives and develops in the high temperatures to which the curd is subjected in the process. Later the *Lactobacillus casei* and *Propionibacterium shermanii* develop to produce the necessary breakdowns and flavors.

In the production of soft cheeses like cottage, Neufchâtel, full cream, Camembert, and others, microorganisms are equally important. *S. lactis* is used to produce the acidity required, and then other organisms are used in the ripening process for those that are ripened. In the case of Camembert a mold, *Penicillium camemberti*, is used.

Cultured cream. A popular use of butter culture is in the preparation of cultured cream. The cream is pasteurized, cooled to 21 to 22° C., and inoculated with butter cultures until an acidity of 0.45 to 0.50 per cent has developed. This cream is relished by all classes of people. Cultured milk and buttermilk are prepared in essentially the same manner.

Acidophilus milk. This is a fermented milk prepared by inoculating sterile or practically sterile milk at 37 to 38° C. with the organism *Lactobacillus acidophilus*. This milk has a therapeutic value in that *L. acidophilus* grows in the intestinal tract and prevents the growth of the toxin secreting putrefactive bacteria. This organism produces lactic acid from lactose in milk to the extent of 2 per cent.

Undesirable Fermentations

Certain microorganisms are capable of producing fermentations decidedly detrimental to the quality of milk and milk products. The dairy farmers and the plant men are seeking to eliminate these microorganisms and thus improve the quality of milk products.

Souring of milk. The formation of lactic acid from lactose and the subsequent souring are usually the first reactions occurring in milk and cream. A number of species are able to ferment lactose, but the most typical representative is *Streptococcus lactis*. Acid formation is rapid be-

tween 30 to 40° C. As a rule, when the developed acidity has reached 0.20 per cent, milk cannot safely be accepted for fluid milk, cheese making, and condensing purposes. When the acidity reaches about 0.55 per cent, the casein is coagulated to form a smooth gel.

Gas production. A most objectionable fermentation occurring chiefly in milk, cream, and cheese is gas production. The causative organisms are found in filth and debris about the barn. Typical examples are *Escherichia coli* found in the intestinal tract of man and animals, and *Aerobacter aerogenes* found universally distributed in nature. Both ferment lactose into gas, lactic acid, and other organic acids. These organisms get into milk as a result of careless methods of production. Their consistent presence is cause to condemn the milk because there is no assurance that other bacteria may not be present that are also detrimental to public health. Gas fermentations rupture and break the body of cheese and in extreme cases render the product unfit for food.

Gas production is frequently encountered in sour cream due to the production of carbon dioxide from lactose by several of the torula, yeast-like organisms. These organisms, prominently mentioned by Hammer,[1] are *Torula cremoris* and *Torula sphaerica*. The cream incurs a yeasty flavor that is carried into the butter. A number of other microorganisms are capable of producing gas in milk and milk products.

Ropiness. In this fermentation milk assumes such a viscous, sticky consistency that it can be drawn out in threads from a few inches to several feet in length. This is due to the ability to certain bacteria to form gum-like substances such as a galactan or a dextrin from lactose. The organism most frequently indicted for this condition is *Bacterium viscosum*, which is frequently associated with stagnant water supplies. However, organisms belonging to the Eschericha-Aerobacter group are capable of producing ropy milk. This fermentation is disturbing because it occurs at temperatures of 10° C. or below in milk from six to eight hours old. Fresh sweet milk is most susceptible; the causative organisms will not tolerate an acid condition.

Sweet curdling. This is sometimes referred to as a sweet fermentation because no appreciable amount of acid is formed in the early stages of coagulation. *Bacillus subtilis*, the type of organism producing this condition, secretes a rennet-like enzyme. Other microorganisms frequently associated with sweet curdling are *B. mesentericus*, *B. cereus*, *B. mycoides*, and *S. liquefaciens*. Some types produce a small amount of acid in the milk, some may cause an alkaline reaction, and others may produce considerable acidity after curdling has occurred. This fermentation is sometimes the cause of considerable annoyance to cheese makers.

Bitter flavors. A number of microorganisms are capable of inducing bitter flavor in milk by a partial decomposition of the proteins to peptones and proteoses. The type organisms frequently implicated are *Pseudomonas fluorescens*, *Aerobacter aerogenes*, and *Torula amari*. The causative organisms

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[1] Dairy Bacteriology, p. 52. John Wiley & Sons, New York. 1928.

grow well at temperatures lower than those required by the lactic acid producing types.

Lipase, an inherent enzyme in cow's milk, particularly in the advanced stages of lactation, may induce bitterness in milk through partial hydrolysis of the butterfat into free fatty acids.

Discolorations. The natural color of milk is sometimes obscured by abnormal fermentations that occur as a result of colored bacterial secretions or of secretions that become colored in acid media. *Pseudomonas cyanogenes* produces a blue color in milk in association with *S. lactis. Pseudomonas synxantha* incites a fermentation with a yellow color forming slowly in the fat layer. A red color may be produced by *Serratia marcescens* and *Bacillus prodigiosus. Torula glutinis* is capable of producing red blotches in milk and cream containing considerable quantities of acid.

Butter held in storage or in transit to market sometimes develops mold discoloration on the surface that is decidedly detrimental to its market value. The chief source of contamination is in the creamery where the pasteurized cream is reinfected after pasteurization by exposure to improperly cleaned equipment, such as pipes, pumps, and churns. Frequently cheese becomes covered with molds in the curing room. The molds most frequently encountered in butter belongs to several genera and include *Penicillium*, *Oospora*, *Alternaria*, *Aspergillus*, and *Cladosporium*. Moldy butter and cheese acquire a musty flavor and aroma.

Fruity flavors. Occasionally milk, cream, butter, and cheese will incur pleasant flavors comparable to those of apples or bananas. This is probably due to the formation of ester-like compounds during the fermentation. A number of organisms have been reported to cause this fermentation.

Putrefactive fermentations. In this category may be included a number of aerobic and anaerobic microorganisms that are capable of decomposing proteins into hydrogen sulfide, methyl mercaptan, peptones, amino acids, fatty acids, methane, indol, and skatol. Representative anaerobes are *Clostridium putrificium* and *Clostridium welchi*, while typical aerobes are *Bacillus subtilis* and *Bacillus mycoides*. These putrefactive fermentations frequently occur in manufactured milk products. Cheese containing a miscellaneous microflora has been known to rot in the curing room, and putrefactive flavors have been frequently observed in butter. With improved methods of producing milk and of manufacturing milk products these fermentations are becoming of minor significance.

Fishy flavors. Certain microorganisms have been alleged to cause fishy flavors in milk, and *Pseudomonas fluorescens* has been prominently mentioned in this connection. *Bacillus ichthyosmius* has been reported from various sources to cause fishy flavors in milk, cream, butter, and evaporated milk. This same flavor defect occurs in salted butter under storage conditions and is due to the dissociation of lecithin to trimethylamine.

It is evident that a number of microorgansims are capable of depreciating the quality of milk and milk products. These fermentations are chiefly due to unsanitary practices on the farm and in the dairy plant

that encourage the presence and the growth of undesirable microorganisms.

A number of examples have been cited to show the practical application of microbiology. From these it is evident that microorganisms may be either the friend or the foe of the dairy industry. When cultured under controlled conditions, microorganisms are utilized to produce desirable flavors and aromas in milk and milk products. On the other hand, every effort must be put forth to exclude the undesirable microorganisms from milk and cream on the farm and in the dairy plant. Milk and its products are extremely susceptible because they contain the food elements necessary for the growth of microorganisms.

MILK AND ITS PRODUCTS IN RELATION TO PUBLIC HEALTH

Milk-borne Diseases

Public health is of vital concern to the dairy industry. Much has been accomplished to eliminate sources of disease in milk and its products, but infrequently epidemics occur without warning that may be the result of carelessness or of ignorance on the part of producers and of plant personnel. Some of the common milk-borne diseases will be mentioned briefly.

Tuberculosis. This is a disease common to human beings and to cattle. Park and Krumwiede [1] showed that 6 to 10 per cent of all deaths in children under five years of age were due to the bovine type of infection. Children become infected chiefly in the alimentary canal, the glands, the bones, and the skin. The tuberculosis organism may get into milk directly from a diseased udder or it may pass through the digestive tract and enter milk by way of unclean methods of production. Raw milk from diseased cows is a potential source of infection for children and livestock. The feeding of raw skim milk has been an avenue for spreading the infection to healthy herds. Many states prohibit the sale of such products until they have been submitted to pasteurization. *Mycobacterium tuberculosis* is the type of organism causing this disease. It will live in milk, but it will not grow at temperatures below 37.5° C. The organism causing tuberculosis is destroyed at pasteurization temperatures; consequently it is not a menace in most manufactured milk products that are pasteurized, with the exception of cheese. Mohler and associates [2] reported that the organisms survived in cheese made from raw milk to which they had been added, and were sufficiently viable to cause the disease in guinea pigs after 220 days.

Undulant fever or brucellosis. This fever is sometimes called Malta fever, named after the island of Malta, where it was found to be associated

[1] Jour. Med. Res. 27:109. 1912.
[2] U. S. Dept. Agr. B.A.I. 26th Ann. Rpt., p. 187. 1909.

with goats' milk. In this country infection has been traced to cows' milk, caused by *Brucella abortus*, the same organism responsible for abortion in cattle. The nature of the disease is now familiar to most physicians so that a diagnosis can be made with a fair degree of certainty. The viability of the causative organisms in milk products made from unpasteurized milk is undetermined.

Typhoid fever. It has been estimated that typhoid fever is responsible for one-half of the diseases traceable to milk and occurring chiefly in small villages and rural communities. Infection usually comes directly or indirectly from a carrier who harbors the disease, but who is usually not aware of being a menace to public health. Such people often constitute the real problem in tracing the source of an epidemic. Water supplies have sometimes been infected with the typhoid organisms. This has serious implications, because there is ample opportunity for the dairy utensils to become contaminated and thus multiply the possibilities for spreading the disease. The causative organism is *Eberthella typhosa*.

Scarlet fever. Sufficient cases of scarlet fever have been traced to infected milk supplies to label this disease a menace to the dairy industry. Milk and dairy equipment are most commonly infected by carriers and convalescents, though epidemics have been traced to returned bottles and dairy utensils from infected homes. Direct contact is the most common avenue of infection. The causative organism is *Streptococcus scarlatina*, and it does not survive long in manufactured milk products. Epidemics have been traced through ice cream infected by carriers.

Septic sore throat. A streptococcus infection of the throat often appears suddenly in severe epidemic form. This disease is very frequently carried in milk supplies and attacks both children and adults. The causative organism is a hemolytic streptococcus that is able to live in the udder, where it may or may not produce a pathological condition. The organism appears to be of human origin and the mode of infection is probably from infected humans to the cow.

Diphtheria. In recent years only a few diphtheria epidemics have been traced through milk supplies. The chief danger of spreading the disease is through carriers or diseased individuals who may expel infected droplets of mucus into milk and on dairy utensils. *Corynebacterium diphtheriæ* is the causative organism.

Infantile diarrhea. This disease, commonly called "summer complaint," causes a large number of deaths among babies and children. According to Newsholme,[1] improper methods of preparing milk in the home for artifically fed babies is responsible for numerous infections. On the other hand, raw milk may contain sufficient numbers of the causative organisms to induce digestive disturbances. Whittaker [2] reported a very significant decrease in infant mortality with the adoption of pasteurization. There are several organisms, chiefly intestinal types, capable of producing

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[1] Jour. Hyg. 6:139. 1906.

[2] Milk Production and Control. The Century Co., New York. 1932. *See* ref. 5, p. 299.

this disease; their appearance in milk usually is due to faulty and careless methods of production on the farm.

The diseases most frequently conveyed through milk and its products have been mentioned; others might be included but their occurrence is infrequent. From the foregoing discussion the consumer may rightfully question: When is milk safe for human consumption? An answer must include a practical consideration of conditions existing on the farms in this country.

Measures for Protection

In the first place, only a few dairymen in the United States are producing raw milk and selling it as such for human consumption. The producing animals are subjected to periodic examination. This involves testing for the common animal diseases. Animals reacting positively are permanently isolated and not allowed to reenter the herd unless consistently negative tests are obtained. The barns and milk rooms must meet certain standards with respect to light, ventilation, and sanitary features. The attendants and milkers must be healthy and submit to periodic health examinations. These in general are the standards under which certified and grade A raw milk of a low bacterial content per milliliter are produced. Raw milk produced under these conditions is as nearly safe for human consumption as possible with our present knowledge of methods of production and detection of disease. The efficiency of this system may be judged by the record that since 1892,[1] only two epidemics of milk-bone diseases have been reported for certified milk. Pasteurization of certified milk is now permitted. Certified milk, which constitutes a very small portion of the total milk produced in this country, commands a premium price; therefore the producer can usually afford the added expense of supervision.

The ultimate goal is complete disease eradication in all herds, but it will be some time before this ideal will be achieved. It is for this reason that practically all the fluid milk sold throughout the United States is pasteurized. Pasteurization is entirely dependable if properly carried out, since this process destroys all pathogens that are commonly responsible for milk-borne epidemics. Careless and unsanitary methods of handling the milk after pasteurization may result in recontamination with disease producing and other undesirable bacteria, but this is no fault of the process. From the standpoint of both public health and the nutritional value of milk there are no strong arguments against pasteurization. The small producer-distributor can reduce the cost factor to a low figure through jointly owned pasteurizing and processing plants.

Pasteurization protects the town and city consumer, but the farmer and his family are still confronted with a health problem. If there is the least suspicion that individuals in the producing herd are infected with animal diseases the raw milk from such cows should not be used in the

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[1] *Ibid.*

household. If the entire herd is under suspicion, then the milk should be pasteurized. Most of the large milk and creamery companies now have inspectors in the field to assist the farmers in improving the quality of their product. State inspectors and veterinarians are likewise co-operating in this respect. Therefore, the farmer has a number of agencies to draw upon, if he will, for assistance in eliminating disease from the producing herd.

The dairy plant and the patron can do much by co-operating to prevent the spread of milk-borne epidemics. One of the largest milk plants in the Northeast has adopted a practical procedure for combating the spread of the common contagious diseases. If a patron's family is taken ill, the milk is withheld from the plant during the quarantine period, but the farmer is paid in full. The plant personnel must report for regular health examinations, and the slightest evidence of disease is reported to the manager.

Very frequently samples of milk are sent to laboratories by dairy farmers and plant men with the urgent request that a bacteriological test be made for some of the common diseases, such as tuberculosis, contagious abortion, and mastitis. In most instances little information of value can be gained from the specimens. These samples are usually in poor condition when they reach the laboratory from having been subjected to warm temperatures in transit, and thus with the bacteriological picture greatly changed. Even if these samples had been properly refrigerated in transit, a long and laborious task would confront the technician to ascertain the absence or presence of the tubercle bacillus in milk. It is true that the common avenue of infection for humans is from milk, but unless the active infection is in the udder, the organism is not regularly discharged in the milk. Furthermore, the organism does not ordinarily grow in milk. It would, therefore, be a long and laborious process to isolate and identify microscopically and culturally the tubercle bacillus in milk in view of its sporadic appearance. The situation might be further complicated by the presence of micoorganisms of similar morphological and cultural characteristics. The laboratory method is to inoculate subcutaneously some of the suspected milk into a small laboratory animal, such as the guinea pig, and wait several weeks or longer for the development of lesions. The same general laboratory procedures apply to the detection of contagious abortion in milk.

The laboratory methods for detecting mastitis or the udder disorders are not so laborious and time consuming. The physical condition of the milk together with a microscopic examination may yield information of value in the hands of an expert.

Chapter 48

COMMON TESTS OF MILK AND CREAM

THE DIFFERENT TESTS APPLIED TO MILK AND ITS PRODUCTS ARE NUMBERED in the hundreds. Only the more commonly used tests for various milk ingredients and some of the tests for quality will be considered here.

SAMPLING

Whatever the test to be determined is, it is essential that the product first be sampled correctly. As has been previously noted, milk fat starts rising as soon as milk stands. Immediately before a sample is taken for analysis or tests, the milk or cream should be thoroughly mixed either by agitation with the proper stirring rod or by pouring it several times back and forth between two containers.

When milk or cream is sour or partially frozen, special precautions must be taken to secure a homogeneous mixture of the whole before a representative sample can be taken. Frozen products must be completely thawed out and thoroughly mixed, as the frozen crystals consist mostly of water, while the liquid portion has an increase in both fat and other milk solids. In sour milk or cream large lumps of curd are frequently present which must be thoroughly broken up and dispersed in order that a representative sample may be taken.

Partially churned lots are difficult to sample. Fairly representative samples may be taken by heating the lot to over 100° F. and thoroughly agitating it to temporarily redisperse the churned fat.

Composite sampling. When samples are to be tested over a period of time, it is generally advisable to combine the daily samples into one sample to save time and work. When this is done (as in creameries which buy cream daily and test it once every two weeks) each sample should be proportionate to the amount that it represents. To have a representative composite sample of two lots of cream of 20 to 40 pounds each, twice as large a sample should be taken from the 40 pound lot as from the 20 pound lot.

Because of the possible great variation in cream, it is essential that each lot be sampled. When milk is purchased, it is customary to take samples at random for from three to six times a month.

Aliquot samples may be taken by a so-called "milk thief," which is a tube that can be inserted to the bottom and filled with the liquid to the level it is in the container—usually a milk or cream can. Proper use of the tube insures aliquot sampling.

Milk is usually sampled with small dippers.

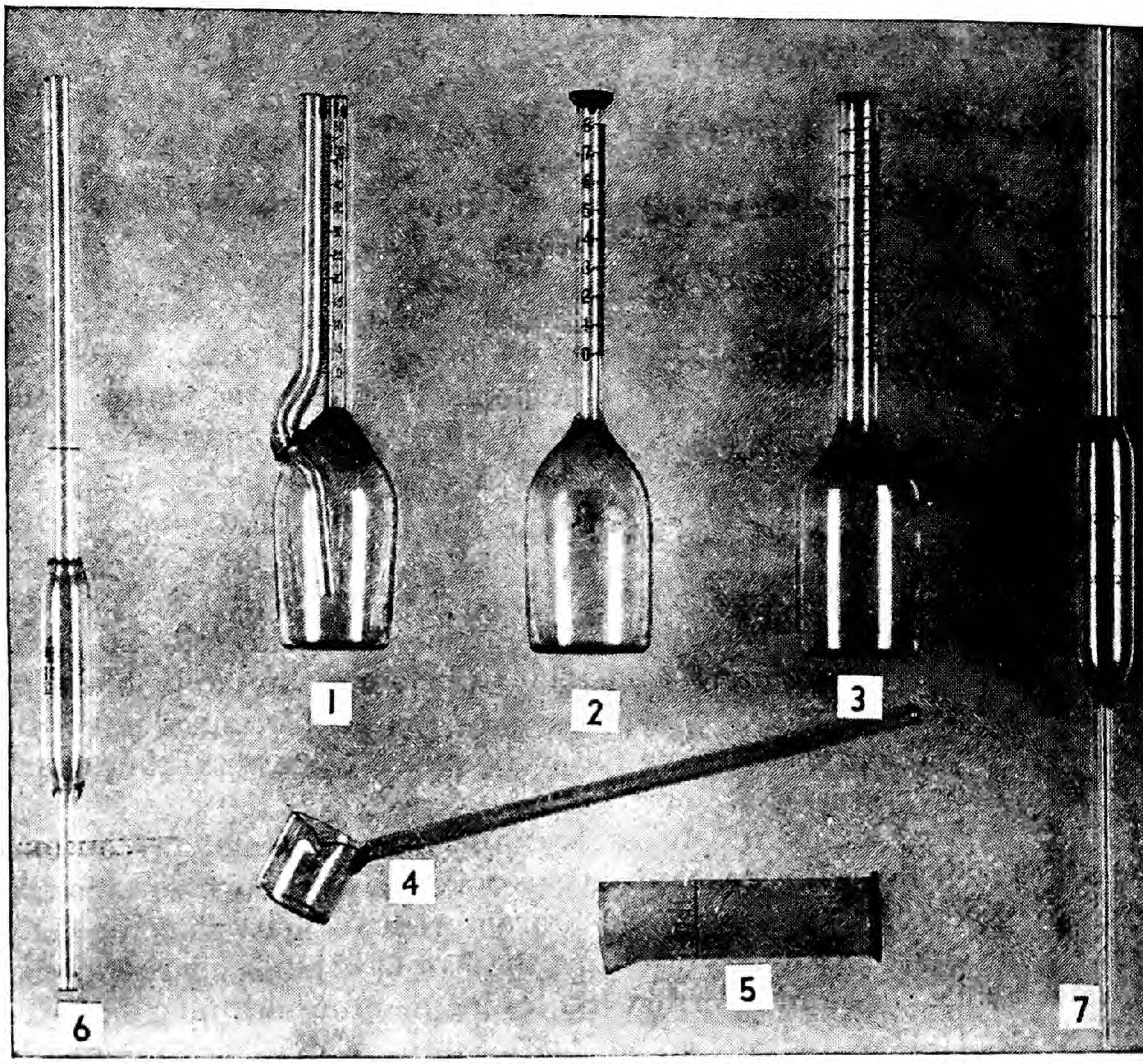


Fig. 120. Glassware needed for conducting Babcock tests on milk, cream, and skim milk: 1, 2, and 3, skim milk, whole milk, and cream test bottles; 4, acid dipper; 5, acid cylinder; 6, 9 cc. pipette used for charging the cream test bottle when weighing; 7, 17.6 cc. pipette used for measuring milk and skim milk.

Sample jars. Any glass bottle or jar that can be tightly stoppered will serve as a composite sample jar. Usually a half-pint size is the most convenient. Composite sample jars must be tightly stoppered to prevent evaporation. Rubber stoppers are the most desirable although good cork stoppers are satisfactory.

Preservatives. There are three different preservatives used for the proper keeping of composite samples. These are formalin, mercuric bichloride or corrosive sublimate, and potassium dichromate. Samples upon which total solids are to be determined should not be preserved with either mercuric bichloride or potassium dichromate as both of these will increase the total solid values, which formalin will not. Any of these preservatives is satisfactory for fat determination, although a little difficulty is sometimes experienced in securing complete digestion of the curd in

conducting the Babcock test when formalin has been used as a preservative.

Since formalin is relatively nonpoisonous, it is the safest of the three preservatives. It is also quite cheap. The disadvantage in its use is that it must be pipetted into the sample jar, while the other two preservatives come in tablet form. One tablet will preserve a pint of milk or cream for two weeks; ½ to 1 cc. of formalin is required to preserve the same amount. Corrosive sublimate, in addition to being extremely poisonous, attacks metals. Potassium dichromate is not so poisonous as the corrosive sublimate and does not attack metal.

FAT DETERMINATION

Most milk and cream is bought and sold upon its fat content whether it is intended for market milk, butter, cheese, or other products. The accurate determination of the fat content of milk and cream is, therefore, not only the most important but the most extensively applied chemical test of milk. Prior to 1890, when S. M. Babcock discovered the Babcock test, the fat content of milk was crudely determined in commerce either by churning a small portion and weighing the butter or by measuring the depth of the cream layer. After the babcock test for fat was developed, it became and still is the standard by which milk and cream is sold in North America. In Europe the Gerber test is the standard. In addition to the Babcock test there are the more accurate but more laborious and costly Roese-Gottlieb test and several others, as the Minnesota Babcock test and the Fucoma, a modification of the Gerber test.

The Babcock Test

The Babcock test is based upon the fact that strong sulphuric acid will digest the fat stabilizers of the milk or milk product and will not attack the fat when it is properly used. In the digestion of the organic material and mixing with the water a great deal of heat is developed which liquefies the fat and facilitates its coalescence. The sulphuric acid increases the specific gravity and lowers the interfacial tension to further facilitate the rising of the fat.

Taking advantage of these facts, Dr. Babcock of the Wisconsin Experiment Station devised glassware to measure the proper amounts of milk and acid, and a milk test bottle in which the reaction could take place and the fat be measured.

Equipment for testing milk. (Fig. 120.) The equipment for testing milk consists of:

1. A milk test bottle with a bulb capacity of 45 to 50 cc. and a neck with a scale graduated so that the fat percentage can be read directly in per cent by weight. One cubic centimeter capacity of the neck is equivalent to 5 per cent of fat, as fat at the temperatures recommended for reading has a specific gravity of 0.9 and 18 grams of milk are used.
2. A pipette of 17.6 cc. capacity. This delivers 17.5 cc. milk, which is equivalent to 18 grams when the specific gravity is 1.032.

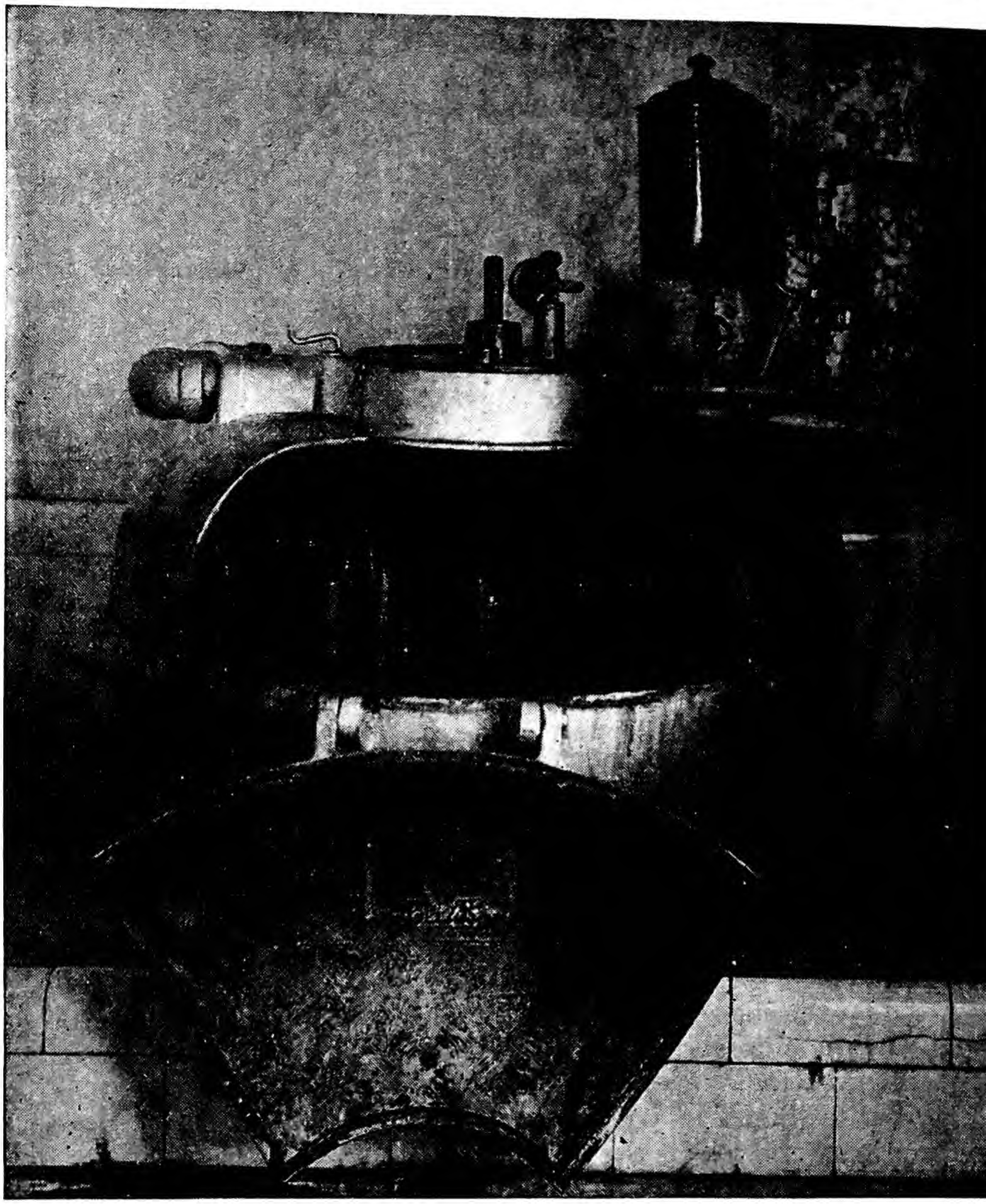


Fig. 121. A steam turbine-driven Babcock centrifuge. Other styles are driven by electric motors or by hand power.

3. A 17.5 cc. acid measure.
4. Commercial sulphuric acid with a specific gravity of 1.83.
5. An appropriate centrifuge. (Fig. 121.)
6. An appropriate water bath.
7. A pair of dividers.

Conducting the test. First the milk is warmed to between 60 and 70° F. and thoroughly mixed. The milk is drawn into the pipette by suction until it is above the 17.6 cc. mark, when the forefinger is quickly placed over the top of the pipette. The milk is then permitted to flow out of the pipette until the upper surface of the meniscus is even with the mark;

then the pipette is inserted in the test bottle and discharged. The last drop is blown out before the pipette is removed. Most pipettes have delivery tubes sufficiently small that they will enter the neck of the test bottle. When this procedure is used, care should be taken to wipe off all milk adhering to the pipette or too much will be discharged into the test bottle. When the delivery tube of the pipette is too large to enter the neck of the test bottle, the discharge is effected by holding the pipette at an angle against the opening of the test bottle and checking the flow with the forefinger over the top of the pipette, so that the milk will flow down one side of the neck and permit air to escape from the test bottle.

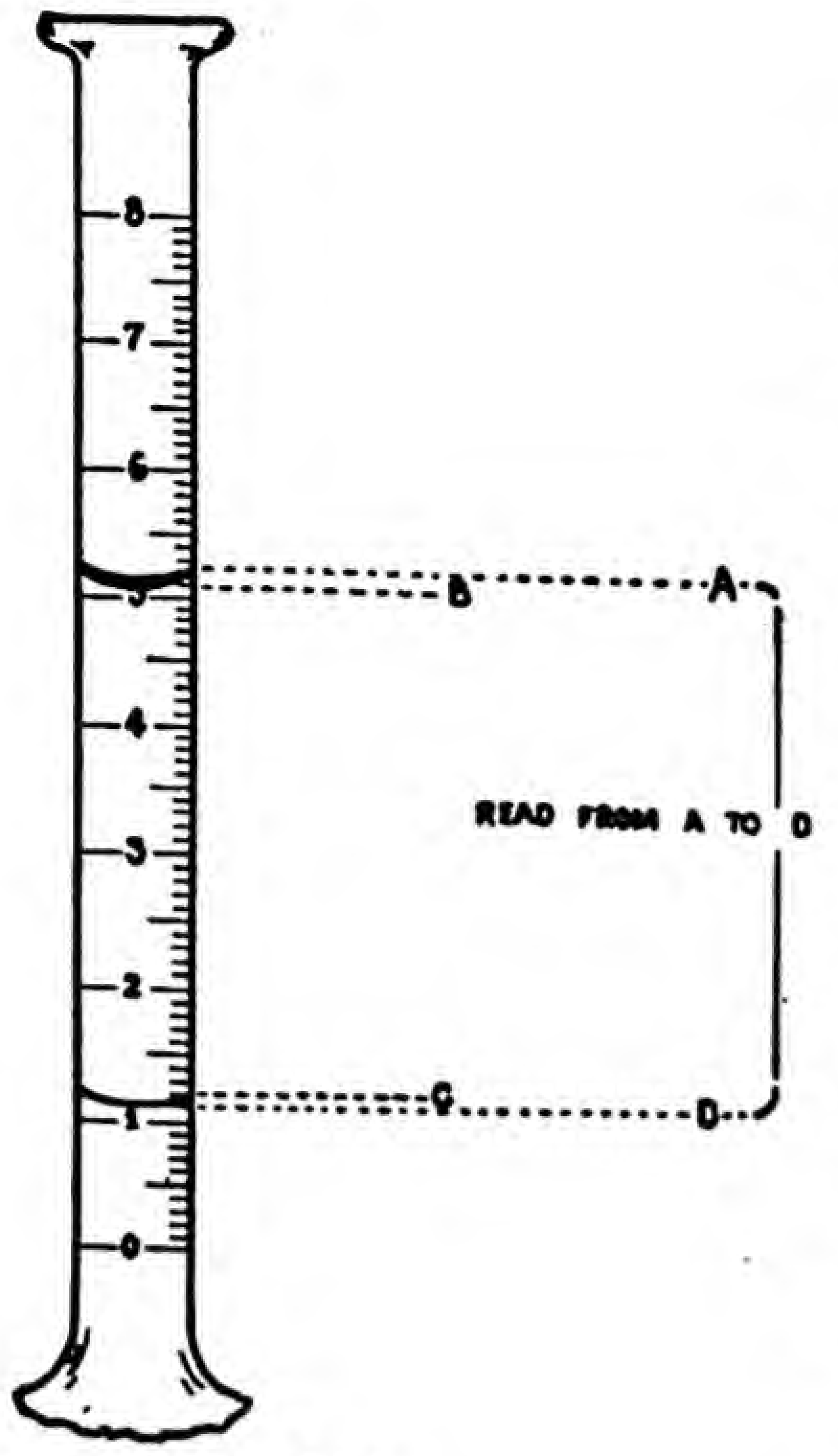
Adding acid. Next, 17.5 cc. of cold commercial sulphuric acid is measured, either in the standard acid measure or in a glass dipper. This is added slowly to the milk, the test bottle being tilted and rotated so that the acid will wash down any milk remaining on the walls of the neck. The acid may be added all at one time, although better results are secured when one-half to two-thirds is added and the sample mixed before the remainder is added. Mixing the acid and the milk is effected by rotating the bottle so that the mixture whirls around the outside wall. Shaking in any way so that the mixture strikes the neck of the bottle will cause the portions striking to be blown out of the bottle, due to the force of vapors generated by the action of the acid upon the milk. If the acid is of the proper strength and the mixing has been thorough, the mixture is from wine to a light coffee color. If it is lighter than this, more acid should be added. If it is too dark, 2 or 3 cc. of water should be added to check the action of the acid.

Centrifuging. The mixed samples should be placed immediately in the centrifuge and whirled for five minutes at the proper speed. The proper speed for the wheel of any centrifuge may be calculated from the following formula:

$$\text{Velocity} = \sqrt{\frac{9 \times 800^2}{\text{Radius}}}$$

Babcock found 800 r.p.m. for a wheel 18 inches in diameter or a radius of 9 inches to be correct. As the centrifugal force at any given speed is proportionate to the square of the radius, the above formula results. On the basis of this formula the proper speeds of centrifuges with wheels of different diameters are:

Diameter of Wheel *Inches*	Speed of wheel *R.P.M.*
10	1,074
12	980
14	809
16	848
18	800
20	759
22	724
24	693



Md. Bul. 401

Fig. 122. Illustrating how the fat column of the Babcock milk test should be read. The reading should be taken from the upper part of the upper meniscus to the bottom of the lower meniscus.

Care must be taken to insure a balance of the bottles in the machine by placing them opposite one another on the wheel. In case an odd number of bottles are to be centrifuged, a balance may be brought about by using bottles filled with water.

After 5 minutes the centrifuge is stopped and hot water is added to bring the contents up to the base of the bottle neck. Unless soft water is used a few drops of sulphuric acid should be added to insure a clearer test. The bottles are then centrifuged for two minutes. Again the centrifuge is stopped, and hot water is added to bring the fat up into the graduated scale of the bottle neck, after which the bottles are centrifuged for one minute.

The bottles are now placed in a water bath at 130 to 140° F. for five minutes. The water bath must be deep enough so that the hot water extends to the top of the fat column. Fat has a specific gravity of 0.9 at 135° F., and as the scale on the test bottle neck is calibrated for fat at that specific gravity, correct temperature is important for accurate testing.

Reading the test. If the test has been properly conducted, the fat appears in the graduated scale of the bottle neck as a clear yellow liquid sharply separated from a clear water below. The fat has two well-defined menisci, one at the top and one at the bottom. The top one is concave and the lower one is convex in relation to the fat. The reading is made from the extreme bottom of the lower meniscus to the extreme top of the upper meniscus. (Fig. 122.) Dividers should be used to secure the height of the fat column, then lowered so one point is at 0; the other point will then indicate the correct fat reading in per cent. (Fig. 123.)

Testing cream for fat. The testing of cream for fat content by the Babcock method is the same in principle as that for testing milk. There are, however, some variations. Cream, because of its varying specific gravity and high viscosity, cannot be accurately measured and, therefore, must be weighed. Because of the high fat content the cream test bottle has a larger neck and a much greater scale than has the milk test bottle. It is usually graduated to read up to 50 per cent.

The cream test bottle may be for either 18 or 9 gram samples. The latter is now more commonly used. When a 9 gram sample is used, only 9 cc. of acid should be added unless 9 cc. of cold water are first added to the cream in the test bottle, when 17.5 cc. of acid should be added. From this point the procedure in testing cream is the same as that for testing milk except in reading the test.

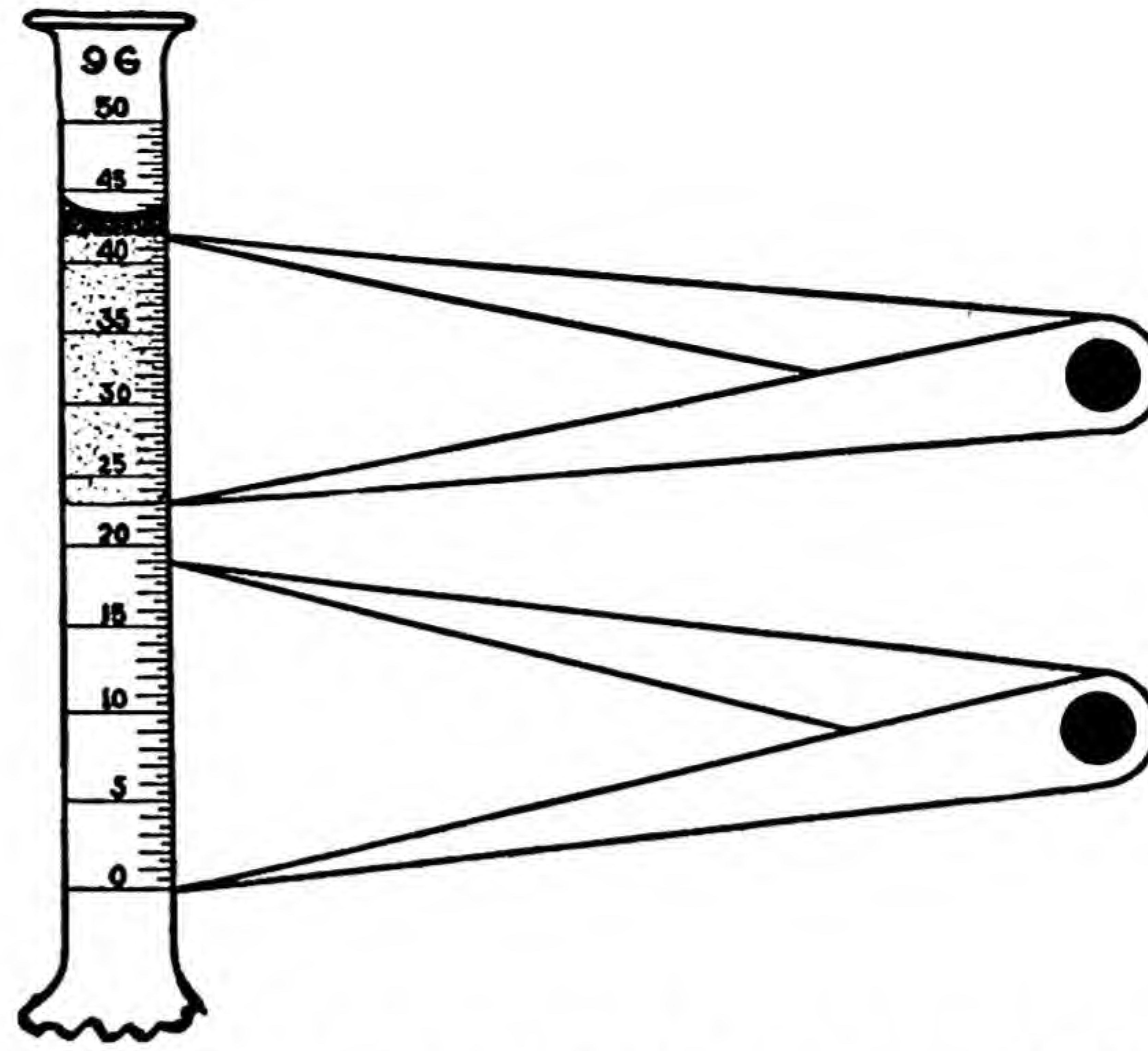


Fig. 123. Illustrating the reading of Babcock cream test. The upper meniscus is destroyed by an oil.

Before the cream test is read, the upper meniscus is eliminated by adding a few drops of so-called red reader. The red reader should be allowed to flow down the walls of the neck to the surface of the fat—never dropped into the fat. After the red reader is added, the test is read from the bottom of the lower meniscus to the flat top surface of the fat. A pair of dividers is used and the procedure is carried out in other respects as for testing milk.

The 9 gram cream test bottle is more accurate than the 18 gram bottle as the bore of the neck is smaller. A longer necked 18 gram bottle having the same bore as the ordinary 9 gram bottle is available. However, a special centrifuge is required for this type of bottle, which is known as the 18 gram 9 inch bottle. The ordinary 9 gram or 18 gram bottle is 6 inches in height.

Attention is also called to the necessity of having accurate balances for weighing cream in the test bottles. Scales known as cream balance scales with provisions for balancing the empty test bottles should be used. These balances should be sensitive to 0.1 gram.

Testing skim milk, buttermilk, and whey. Because these products contain such small amounts of fat, a specially constructed test bottle is used. This bottle has two necks: one that is used for charging the bottle with the materials, and one that is a fine bore tube graduated in 1/100 per cent for reading the fat. In testing skim milk and buttermilk it is advisable to use 20 cc. of acid added in 2 portions of 10 cc. each. When whey is tested only 10 to 12 cc. of acid should be used, as the solids content is much lower than that of skim milk or buttermilk. The test bottles should be placed in the centrifuge with the filling tube toward the center of the wheel. In all other details the test is carried out in the same manner as for the testing of milk.

When buttermilk or whey contains more than 40 per cent of fat, a 9 gram sample should be used. When this is done, only one-half as much acid is used and the fat reading is doubled to give the correct percentage.

Modified Babcock test for buttermilk. The Babcock test is not satisfactory for buttermilk, because the values are much lower than the values secured by ether extraction. It is also difficult to obtain clear tests because the fat column is usually contaminated with a dark material. By adding normal butyl alcohol and thoroughly mixing it with the buttermilk before

the acid is added, a clear test is secured that agrees very well with the ether extraction method. This is commonly known as the butyl alcohol test. In all probability the lecithin of the buttermilk as well as the milk fat is recovered by this method. This test, therefore, represents higher values than the actual butterfat in buttermilk.

Two cc. of normal butyl alcohol is added to 9 cc. of buttermilk, and to this 7 cc. of sulphuric acid is added. The reading of the fat column is doubled to secure the correct fat percentage.

Causes of poor test. Unless the fat column is of a clear amber color, free from contamination of other material, and has well defined upper and lower surfaces, it cannot be reliable. Frequently because of some fault in the technique the following defects are encountered:

1. The fat column is dark colored.
2. The fat column contains black particles of varying sizes.
3. White or grayish particles are dispersed throughout the fat.
4. The upper meniscus (in milk testing) is not well defined due to bubbles or other material.

The dark color of the fat column is due to a too vigorous action of the acid. This may be caused by the use of too much acid, too strong acid, or by having the milk or acid or both too warm when mixing. If a too vigorous action is noticed immediately after mixing, the action may be checked by adding a few cc. of warm water. If the acid is too strong, the trouble is corrected by using less acid.

The most common defect in Babcock tests is a fat column contaminated with black particles. The most common cause of this defect is improper mixing of the acid and the product tested. When the acid first comes in contact with the milk it becomes curdled. Next, the curd particles with the fat they contain are charred on the surface and further action by the acid is inhibited or stopped unless the sample is vigorously shaken. The charred particles rise up into the fat column because of the fat they contain. To avoid this defect, the mixture must be agitated thoroughly. It is a good plan to continue to agitate the sample for about a minute after all visible particles appear to have been dissolved.

White or grayish particles found in the fat column indicate that too little, too cold, or too weak acid has been used; they may also be due to insufficient agitation. Adding water before the action is completed will produce the same results.

The appearance of bubbles on the surface of the fat column to partly obliterate the meniscus is usually due to carbonates in the water that is added. When such water contacts the acid, carbon dioxide gas is given off. The remedy lies in treating the water with a few drops of acid before adding it to the test bottle.

The Minnesota Babcock Test

The Minnesota Babcock test is used for the fat determination of all dairy products. It makes use of the standard Babcock glassware but it

differs from the Babcock test in the reagent and the procedure used. The reagent is alkaline, consisting of sodium salicylate, potassium carbonate, potassium hydroxide, sodium ricinoleate, an alcohol, and water. The reagent is manufactured by Nafis-Kimbal Glassware Company of Chicago. It is put up in dry form and may be made up when it is to be used by the addition of the water and alcohol solvent. This reagent is much safer to use than is sulphuric acid.

In conducting the test, the standard glassware is charged in the same manner as for the Babcock test. Instead of acid, the Minnesota Babcock reagent is added—20 cc. to 18 gram samples of milk, skim milk, and buttermilk, and 10 cc. to a 9 gram sample of cream. The reagent and the sample are thoroughly mixed by shaking. The samples are then heated in a hot water bath (about 180° F.) for five to ten minutes, or until the fat appears separated out and the milk solids are completely dispersed. They are then centrifuged for one or two minutes, after which hot water is added to bring the fat into the graduated scale of the bottle neck. After the bottles are centrifuged again for one minute, they are placed in a hot water bath and read as for the Babcock test.

The Minnesota Babcock test reagent keeps the phospholipids is suspension. For this reason in testing buttermilk considerably lower values will be observed than when the butyl-alcohol test is used.

The Roese-Gottlieb Method

The Roese-Gottlieb method of determining fat in milk and other dairy products is generally considered the most accurate and, therefore, sets the standard by which other tests are judged. This method, which is embraced in the Mojonnier method, is used on all dairy products where great accuracy is desired. It is not generally used because the equipment and reagents required are expensive, and also because a great deal of time and labor is involved in making the determination.

Details for making the determination will not be given here; a brief consideration of the basic principles of the test will suffice. Samples of the product to be tested are accurately weighed on a chemical balance into appropriate receptacles. Ammonia is added to neutralize the acid that would otherwise be soluble in the ether. Then alcohol is added to facilitate the mixing with ether. Both ethyl ether and petroleum ether are used. After a thorough shaking, the supernatant ether is decanted off from the aqueous portion into an evaporating dish that has been carefully weighed on an analytical balance. Two more ether extractions are made and added to the evaporating dish, which is now heated to evaporate off the ether, alcohol, and water. The last part of the evaporation is done in vacuum at 100° C. The dish is then weighed on an analytical balance. Any increase in weight is due to the extracted fat.

DETERMINATION OF TOTAL SOLIDS

The determination of total solids of milk and milk products is frequently desired. In some markets a minimum total solids content is set for milk to

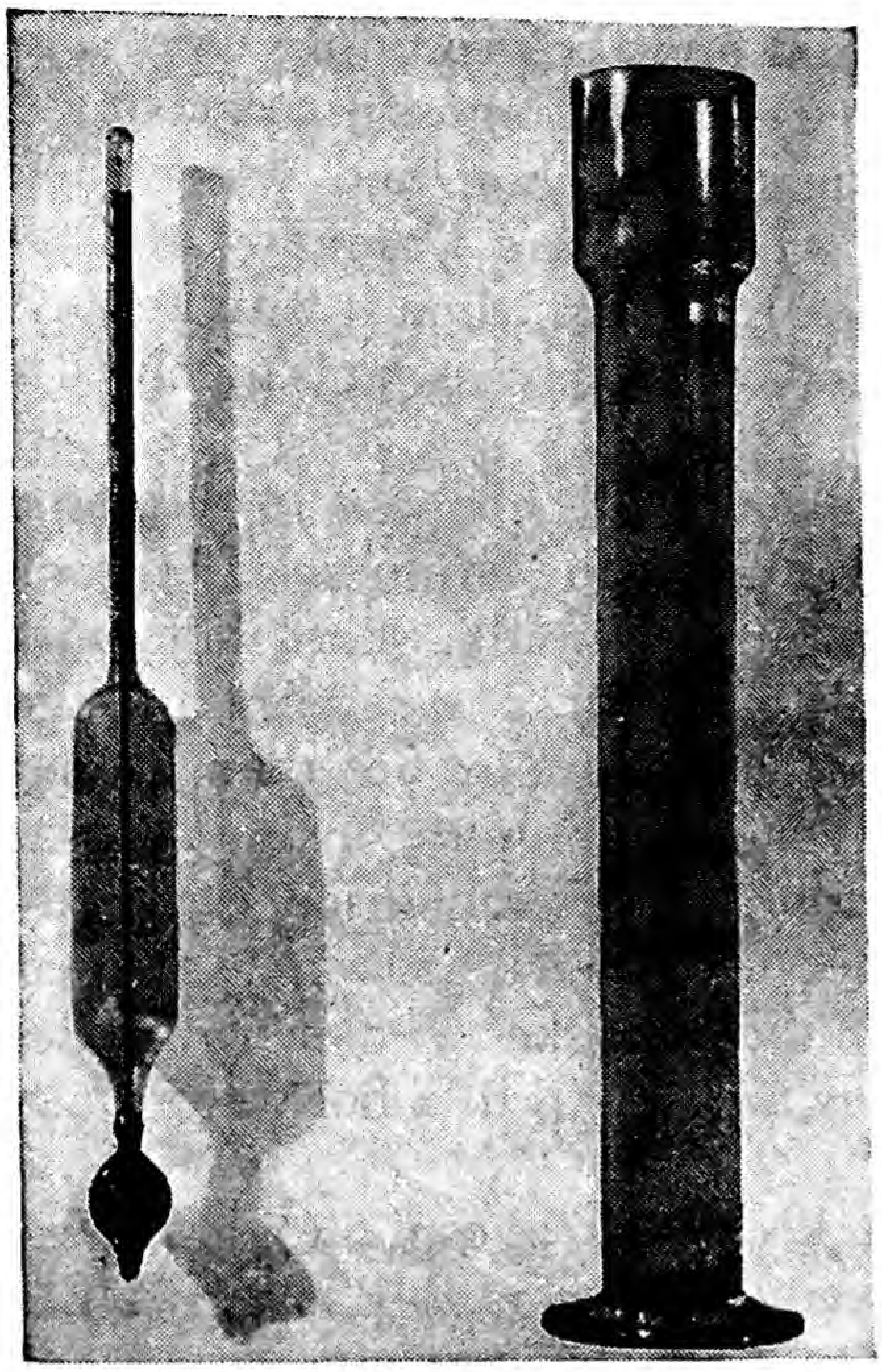


Fig. 124. A lactometer and cylinder.

be sold. The total solids of milk should be known for ice cream making, for the production of condensed and evaporated milks, and for other purposes. There are two ways of determining the total solids of milk. One is calculated from the lactometer reading and the fat percentage; the other is determined by the actual drying of a sample of milk.

By the lactometer. As has previously been stated, the total solids of milk may be approximately estimated from the lactometer reading and the fat percentage. The formula is:

$$\frac{L}{4} + 1.2F$$

L is the reading of the Quevenne lactometer, and F represents the fat percentage. (Fig. 124.)

By the Majonnier method. The Majonnier tester, also used to determine the fat by the Roese-Gottlieb method, is used extensively in determining the total solids or dry matter of all dairy products. The Majonnier method of determining total solids in milk is essentially the official method.

By this method 2 or 3 grams of milk are accurately weighed by the analytical balance in a tare, a flat bottomed metal dish. The moisture is driven off on a hot plate under vacuum. After proper cooling, the dish with its dried contents is again weighed. From the weight of the sample used and the dry matter found the per cent of total solids can readily be calculated.

DETERMINATION OF CASEIN

Determination of the amount of casein in milk is of practical importance in cheese making and in the making of casein. There are several methods by which casein may be determined. The oldest and probably most commonly used method is that of Walker. In this test 9 cc. of milk are run into a white porcelain container and 1 cc. of phenolphthalein solution is added. Now tenth-normal sodium hydroxide is added until a pink color appears. Next 2 cc. of a previously neutralized (to phenolphthalein) solution of 40 per cent formalin are added, and the mixture is thoroughly stirred with a glass rod. The sodium hydroxide solution is again titrated until the pink color appears. The number of cc. of sodium hydroxide used to neutralize the solution after the addition of the formalin is multiplied

by 1.47 to give the percentage of casein in the milk. This test cannot be used on milks containing preservatives.

DETERMINATION OF QUALITY

Determining the acidity of milk. Determination of acidity is essential in nearly all processes in the dairy industry. The amount of acid in milk, cream, or other product constitutes a measure of its freshness and condition. A knowledge of the amount of acid present in milk is essential for cheese making. The butter maker, too, must know the amount of acid in the cream used for churning.

There are two types of acidity in milk: the apparent acidity, and the acidity due to lactic acid. Fresh milk titrates from 0.1 to 0.2 per cent, or an average of 0.15 per cent lactic acid equivalent. This titration is not due to lactic acid but to the phosphate and protein buffers present in the milk. The acidity developing in milk after it is drawn is due to lactic acid formed from a breakdown of lactose by bacteria.

The basis for the acid test is that alkali will neutralize acid; 1 cc. tenth-normal alkali will neutralize 1 cc. tenth-normal acid. As 1 cc. tenth-normal lactic acid contains 0.009 grams lactic acid, the per cent of acidity in terms of lactic acid can be calculated by the following formula when tenth-normal alkali is used for titration:

$$\frac{\text{cc. N/10 alkali} \times 0.009}{\text{Grams of sample}} \times 100 = \text{Per cent lactic acid}$$

In practice 17.6 cc. or 18 grams of milk are most commonly used. The milk is placed in a white porcelain cup with 1 cc. of the phenolphthalein solution and titrated with N/10 sodium hydroxide solution to a faint pink. When 18 grams are used the number of cc. of N/10 alkali solution required for the titration is divided by 2 to give the percentage of lactic acid equivalent. If 9 grams of the sample are used, the number of cc. of alkali used represents the per cent acidity.

Sediment test. The amount of foreign material in milk is usually a fair indication of how cleanly it has been produced and handled. There are three general methods by which an estimate of the amount of sediment in milk may be arrived at. These are: settling by standing, filtration, and centrifuging. By letting 4 ounces of milk stand in an ordinary vial for two hours a rough estimate may be made of the amount of sediment in the milk from the amount that has settled to the bottom. The amount of sediment on the bottom of an ordinary milk bottle in milk that has stood for some time is also a fair indication of the amount of dirt present in milk.

A better indication of sediment in milk is secured from filtering a sample through a filter pad. A number of mechanical devices are on the market that facilitate forcing 1 pint of milk through a standard cotton filter disc. When the disc is dried, the amount of sediment may be observed.

A third method is placing a sample of milk, usually 10 cc., in a pointed

graduated test tube and centrifuging in a high speed centrifuge. The amount of sediment may then be determined from the thickness of the layer collected at the bottom of the tube.

The brom-thymol-blue test. In recent years it has been established that mastitis milk usually turns alkaline in its reaction. A test for alkalinity, while not infallible, is about as reliable a test for mastitis as is known. Colostrum milk and milk retained in the udder for two or more days is also alkaline in reaction. Brom-thymol-blue turns from a yellow in acid to a blue in alkaline solutions. The point where it turns blue is about the point where alkalinity in milk indicates mastitis. The test, to be of any value, must be run on fresh milk. It is quite common practice to make the test in the barn when the sample is taken.

To 10 cc. of milk in a test tube is added 1 cc. of the brom-thymol-blue solution. Normal milk becomes a grayish yellow, while mastitis milk turns blue. A sample of milk known to be normal should be set up with the brom-thymol-blue solution, to be used in comparison with the sample in question. Cows should not be condemned upon one positive reaction of the milk to brom-thymol-blue. Several samples should be taken and tests run; and for positive diagnosis of mastitis, other considerations, such as clinical symptoms, should be taken into account.

Alcohol test. Of the large number of tests used to determine quality in milk the alcohol test must be mentioned because of the simplicity of the test. Equal parts of milk and 72 per cent neutral alcohol are mixed in a test tube and inverted. If the milk is of high quality the walls of the test tube will be clean and free from curd particles. If the milk has high acidity (0.21 per cent or more), is from diseased udders, is colostrum, or is high in coagulating enzymes, the walls of the test tube will present small white particles of curd.

Methylene-blue reduction test. Because methylene blue loses oxygen to oxygen consuming enzymes to form a colorless compound, this dye becomes a valuable one in determining the bacterial activity in milk or cream. The process of removing oxygen from a compound is known as reduction; hence this test is also known as the reduction or reductase test.

A stock solution of methylene blue is made up by dissolving 1 gram of the cyrstalline dye in 2,000 cc. of water. Immediately before use, this is diluted in the proportion of 1 cc. to 10 cc. of water. One cc. of the diluted solution is added to 10 cc. of milk or cream in a test tube and mixed by inverting. The tubes are set in an incubator at 37.6° C. and examined at certain intervals for color change. The rapidity with which the blue color disappears has been found to correlate with the bacterial activity of the

Time for Color to Disappear	Number of Bacteria per cc.	Quality of Milk
Less than 20 minutes............	Over 20,000,000	Very bad
20 minutes to 2 hours...........	4,000,000 to 20,000,000	Bad
2 hours to 5½ hours............	500,000 to 4,000,000	Average
More than 5½ hours............	Less than 500,000	Good

milk. The relationship between the time at which the color disappears, the quality of the milk, and the number of bacteria is shown above.

Other tests. Other tests for quality of milk include fermentation tests, the catalase test, and others.

TESTS FOR HEATED MILK

In milk control work, it is very desirable to have tests that will tell whether milk has been pasteurized. There are three common tests, all based upon enzyme activity, that are employed for this purpose. These are Schardinger's test, the Storch test, and the Arnold test.

Schardinger's test employs a reagent known as Schardinger's reagent. This reagent consists of 5 cc. of saturated solution of methylene blue, 5 cc. of formalin, and 190 cc. of water. The test is performed by adding 1 cc. of Schardinger's reagent to 20 cc. of milk and warming it to 113 to 122° F. The time required to lose the blue color indicates the degree to which the milk has been heated. The reduction in color is due to the enzyme, reductase, which is destroyed at temperatures above 100° F.

The Storch test employs the oxidizable dye, para-phenylene-diamine, in a 2 per cent solution. To 5 cc. of milk in a test tube is added 1 drop of a 0.25 per cent solution of hydrogen peroxide and 2 drops of the para-phenylene-diamine solution. Unheated milk or milk heated less than 172° F. produces an intense blue color.

The Arnold test employs a 5 to 10 per cent quaiac solution in acetone. When a few drops of this solution are added to normal milk or milk heated to less than 176° F., a blue color appears in a few minutes. If heated above 176° F. no color will appear.

No absolutely reliable test for heating at ordinary pasteurization temperatures has as yet been developed.

Phosphatase test. The recently introduced test of Kay and Graham,[1] known as the phosphatase test, promises to be the most reliable for determining whether milk has been pasteurized. The test is based upon a measure of phosphatase activity in the milk and is therefore a test for pasteurization, as pasteurizing temperatures inhibit phosphatase activity in proportion to height of the temperature and the time subject to the heat.

The test is rather complex, requiring special reagents which, together with instructions and equipment, may be secured from technical supply houses. Health officers in different cities are working out techniques of the test for their conditions. For this reason there are many modifications of the original test, and several years will be required before the test will become adequately standardized.

[1] KAY AND GRAHAM. Jour. Dairy Research 6: 191. 1935.

Chapter 49

THE MORE COMMON DAIRY PROCESSES

THE PROCESSING OF MILK COMMENCES IMMEDIATELY AFTER IT IS PRODUCED on the farm. The types of processing that milk and its products pass through depends upon the type of product to be manufactured. It is not possible here to treat in detail all of the dairy processes, but only to consider the more common ones. The processes used on the farm will naturally be dealt with more fully than those employed in plants after the milk leaves the farm. Every student of dairying, however, should be somewhat familiar with the fundamental principles involved in the more common processing of milk. In subsequent chapters the basic principles involved in the manufacture of various dairy products will be considered. In this and in the next chapter will be considered the farm processes of straining, separation, and cooling, and the transport, clarification, filtration, pasteurization, cooling, and emulsification of milk after it leaves the farm.

STRAINING MILK

Straining milk is probably one of the oldest of dairy processes. It is effected on the farm by passing milk through a variety of materials to remove the coarser particles contained therein. The strainer may be a fine wire gauge, of cheesecloth or other cloths, cotton batting, or special strainer pads. Cotton batting or special strainer pads are the most efficient strainer materials.

None of the materials used for strainers will remove all the foreign material in milk as the finer particles will pass through. Straining may reduce bacterial content of milk by removing particles laden with bacteria before they become dispersed throughout the milk. In case cheesecloth or other cloth is used and reused after washing, the strainer may be an important source of bacterial contamination. It is preferable to use cotton batting and filter pads that may be thrown away after they are used. When cloths are used as strainers, they should be thoroughly washed and sterilized by boiling immediately after each time they are used.

SEPARATION

About one-half of all milk produced is separated on the farm or near-by plants. While cream may be separated from the skim milk by natural rising and hand skimming, most milk is now separated by the mechanical cream separator.

Gravity creaming. The phenomenon of fat rising by natural gravitation has been discussed previously. In practice this phenomenon has been

taken advantage of in the production of cream. Three general methods of natural creaming have been resorted to. These are the shallow-pan, deep-setting, and water-separation methods.

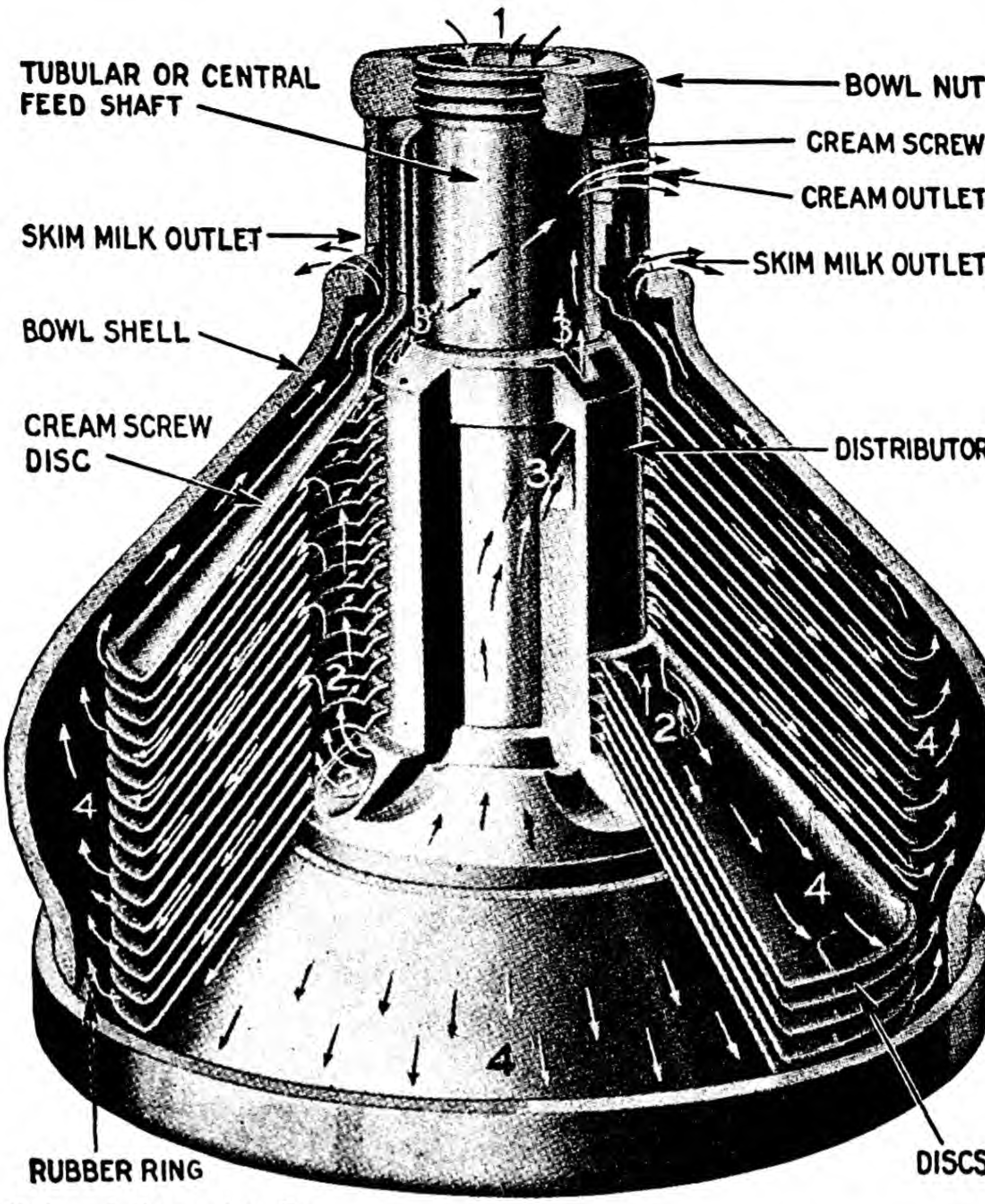
The shallow-pan system, as the name implies, consists of setting the milk in a shallow pan (usually 4 inches deep) for 24 to 36 hours, and then removing the cream by a "skimmer." The milk is usually coagulated from souring after being skimmed. While the system is still practiced in some places it is almost completely supplanted by the mechanical separator. The skim milk from the shallow pan system contained from 0.5 to over 1 per cent of fat.

The deep-setting system uses deep (20 inches high) straight sided pails which, when filled with milk, are set in cold water. From 12 to 36 hours are required for setting before skimming. The cream is removed by a dipperlike "skimmer," or the skim milk is removed by a faucet placed at the bottom of the pail. When the latter method is used, the pail is equipped with a strip of glass in the wall near the bottom so that the demarcation between the cream and skim milk may be observed. The cream produced by this method is low in fat content, usually about 20 per cent, and the fat losses in the skim milk are somewhat lower than by the shallow pan method.

Water separation was never extensively used because it was not satisfactory. In this system the milk was diluted with cold water with the idea that dilution would lower the resistance to the rising of the fat. Because of the dilution the fat particles had to travel farther and any advantage gained from lowering of resistance was lost. In the aggregate more fat was lost in the skim milk than by the deep-setting method, and the value of the skim milk was lowered because of the dilution.

The centrifugal separator. The invention of the centrifugal separator has influenced the dairy industry probably more than any other single factor. Rapid and efficient separation of cream from milk has made possible the handling of milk from large dairy herds—a large-scale enterprise that would not have been possible if the slow, laborious method of setting the milk either in shallow pans or deeper pails had had to be followed. The use of the cream separator both on the farm and in the plant has done much to establish the present system of production and manufacturing of dairy products of all kinds.

The first successful continuous centrifugal separators were first marketed in 1878. Dr. Gustav DeLaval of Sweden is usually credited with being the inventor of the cream separator. Nielsen and Winstrup of Denmark, however, are said to have produced successful continuous separators in the same year. Prior to 1878 a great many separators had been devised using the centrifugal principle, but with the exception of one they were not continuous. They consisted in the main of receptacles of various descriptions that were filled with milk and revolved around an axis, and then stopped, the cream being then removed. The one exception to this type was the continuous separator invented by Prandtl of Germany in 1875. This was undoubtedly the first continuous separator. As



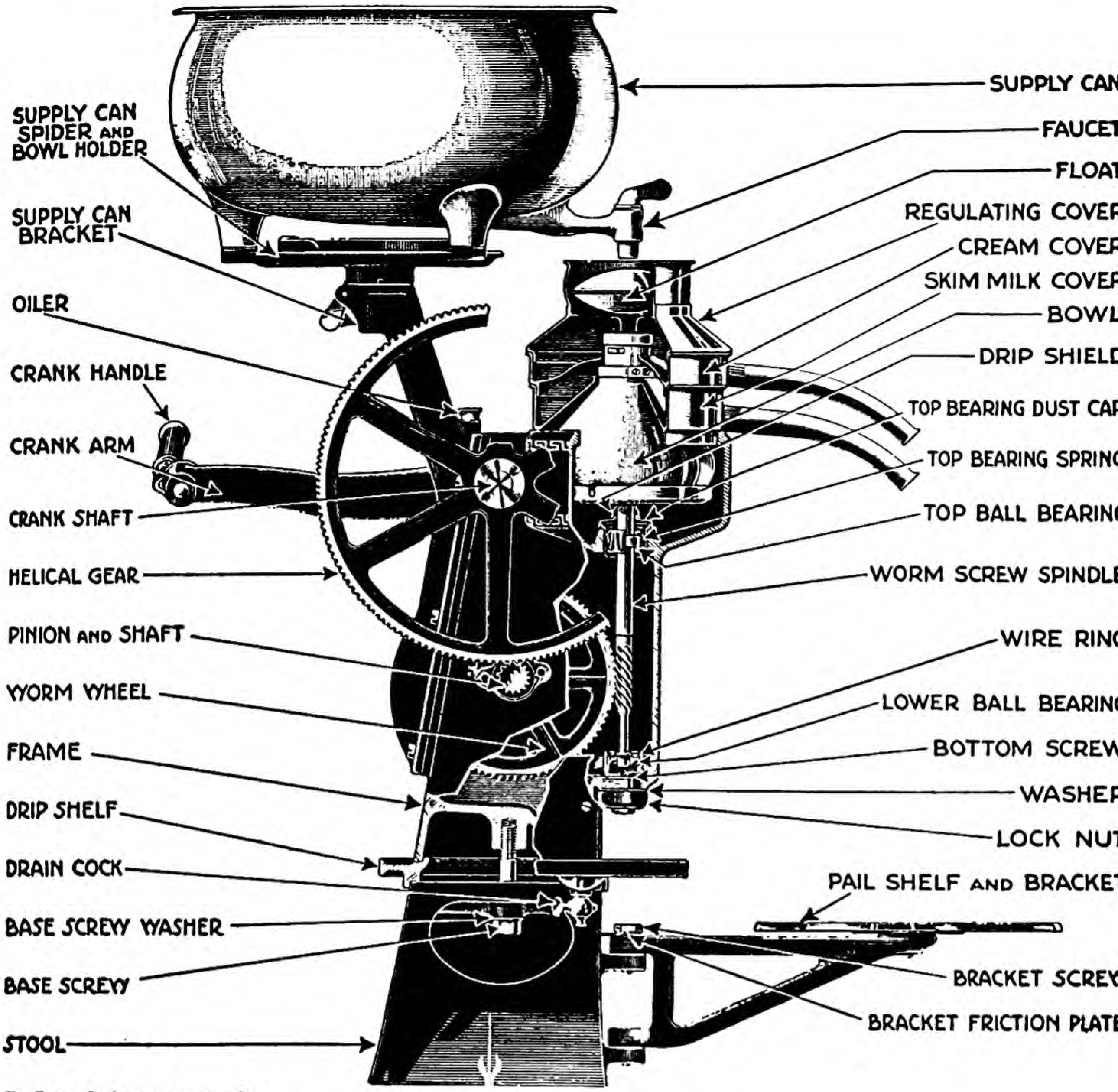
DeLaval Separator Co.

Fig. 125. A cross section of a separator bowl showing the construction and paths of the incoming milk and the outgoing cream and skim milk. The milk enters the bowl at (1), passes down the tubular shaft, and comes out of the slots at (2). The lighter cream passes toward the center (3), and the skim milk (4) passes toward the outside.

this machine was not manufactured for practical use, Prandtl is not generally credited with the invention of the first cream separator.

Principle of separation. Cream is rapidly removed from milk in mechanical separation because the difference between the specific gravities of the fat and skim milk has been greatly increased. One cc. of fat weighs approximately 0.9 grams, and the same quantity of skim milk weighs 1.036 grams; there is, then, a difference of 0.136 grams. This difference is sufficient to cause most of the fat to rise to the top if it is given time.

In the mechanical separator the centrifugal force created increases the gravity by about 1,000 times. The relative difference, therefore, between the fat and skim milk in the speeding separator bowl becomes 136 instead



DeLaval Separator Co.

Fig. 126. The parts and principal mechanical features of a cream separator.

of 0.136, as when standing, and the fat separates almost instantly from the skim milk toward the center of the bowl.

Mechanical construction. While there are many different makes of separators on the market and each one differs from the other in some respect, all are constructed upon the same basic principle. This basic principle is some device for removing the material from the outer portion of the bowl, which is the skim milk, separately from the material toward the center of the bowl, which is the cream.

The bowl in the early separators was hollow. Later it was found that separating the milk into thin sheets within the bowl facilitated separation. Two general types of devices inside the bowl were used: one commonly known as the disc, and another known as the link blade. The disc type, which entirely dominates the separator types today, consists of a series of discs kept slightly apart and stacked upon one another to fill the bowl. A cross section of a representative bowl is shown in Figure 125. The es-

sential mechanical features of the bowl in addition to the discs are given below.

1. The shape of the discs—inverted cup shape.
2. Facilities for the milk inlet through the center of the bowl down toward the bottom.
3. A space between the bowl wall and the discs for the skim milk to pass upward and out through the skim milk spout; also room for the collection of the separator slime.
4. Facilities for the cream to pass upward in the center of the bowl to exit through the cream screw.
5. A divider disc (the top disc) which separates the skim milk from the cream although the outlets for both are close together.

The rapid separation of the cream from the milk is effected in the outside of the bowl, where the pressure is the greatest. Both skim milk and cream are let out close to the center of the bowl at lower pressure; this is made possible by the divider disc, which keeps the skim milk on the outside and the cream on the inside.

The other parts of the separator consist of the machinery required for getting the necessary speed for the bowl, a supply tank for the milk to be separated, and the mechanical equipment needed to carry the skim milk and cream away from the bowl. These are illustrated in Figure 126 for a typical modern separator.

Capacities of separators. Separators are made in a great range of sizes. Farm separators may be secured with capacities from 100 to 1,000 pounds of milk per hour. For factories separators ranging from 1,500 to 12,000 pounds capacity per hour may be obtained. As a rule the factory separator differs from the farm separator only in size. There is, however, a factory separator in which the milk enters from the bottom of the bowl by being forced there through airtight tubing. In this type the cream comes out of the bowl at the top and in the center. The rate with which the cream comes out is regulated by the pressure applied to the milk entering the bowl.

The cream screw. Each machine has a device for regulating the richness of the cream. This is done by changing the proportions of material coming out of the cream and skim milk openings, either by changing the pressure on either of the two or by changing the size of the opening. In most machines the richness of the cream is regulated by means of a "cream screw" and in a few by a "skim milk screw." When the cream screw is turned in closer to the center of the bowl, the pressure is decreased and less flows through, making a richer cream. Closing the size of the opening has the same effect, while enlarging the opening or turning the cream screw out lowers the richness of the cream by increasing the amount.

In machines having "skim milk screws" the richness of the cream is affected in the opposite manner. Turning the skim milk screw out in-

creases the amount of skim milk and lessens the amount of cream, and hence richer cream results; and turning it inward reduces the amount of skim milk and increases the amount of cream.

Other factors influencing richness of cream. Without changing the cream or skim milk screws, the fat content of machine separated cream varies from time to time for a number of reasons. The chief factors influencing the richness of cream are as follows:

1. Speed of the machine
2. Richness of the milk separated
3. Rate of inflow
4. Temperature of the milk
5. Dirt in the bowl
6. The amount of water or skim milk used in flushing the bowl

Speed of machine. As the speed of the separator is increased, the fat content of the cream produced is increased. The effect of increased speed varies with different machines and the richness of the cream. With the cream screws set to skim 40 to 50 per cent cream at normal speeds, when the speed is reduced to one-half, the fat content of the cream is reduced by one-third to one-half. Lower testing creams are not affected nearly so much; a 20 per cent cream at normal speed is seldom reduced to below 17 per cent at half speed.

The reasons for these differences become clear when one considers the fundamentals of the physical forces involved in mechanical separation. The cream outlet is nearer the center of the bowl than the skim milk outlet, and consequently is less subjected to the centrifugal forces. With increasing speed the greater pressure forces out more skim milk, leaving less for the cream outlet. When the cream screw is set for lower testing cream, it opens up farther from the center of the bowl and nearer the skim milk outlet and, consequently, is affected more nearly the same as the skim milk outlet by changes in speed.

Richness of milk. With any increase in the fat content of the milk, the fat content of the separated cream will also increase. The increased fat content of the cream is a little more than a proportionate increase in the fat content of the milk. Cream from a 6 per cent milk is a little more than twice as high in fat content as cream from a 3 per cent milk. The separator is set so that a certain proportion of the intake will come out of the cream and skim milk openings respectively, when the inflow and other factors are constant. When the fat content of the milk is increased the cream becomes richer and more viscous, thus offering more resistance to flow; and as a result less cream is produced, and there is a corresponding increase in fat percentage.

Different separators vary in the effect of richness of milk upon the richness of cream. If a 3 per cent milk produces 20 per cent cream, a 6 per cent milk can be expected to produce about 42 per cent cream.

Rate of inflow. The rate with which milk comes into the bowl influences the fat percentage of the cream markedly. The fat percentage decreases with increased inflow of milk. By reducing the inflow of the ordinary separator sufficiently, as high as 75 per cent fat cream may be produced, as compared to 40 per cent for normal inflow. This phenomenon is entirely in accord with physical laws and is explained on the basis of pressure. When the inflow is slow, the skim milk opening is able to let out nearly all the milk, thereby lowering the pressure at the cream opening. This results in less cream with a higher fat content.

In practice the rate of inflow of milk may be changed by damage to the float, failure to fully open the faucet, or by change in the height of the milk in the supply tank. In some cases when the float ceases to function, the inflow is speeded up to a point where the cream becomes exceedingly low in fat content.

Temperature of the milk. As the temperature of the milk is lowered, the fat content of the cream produced becomes higher. This is due to the fact that with lowered temperatures cream becomes more viscous and resistant to flow. The amount passing through the cream opening in the bowl is reduced, with a resultant increase in richness. Milk heated to higher temperatures than normal when separated will produce cream of a lower fat content, due to the fact that at high temperatures cream is more fluid. The effect of low milk temperatures upon the fat content of cream varies with different machines. If the cream contains 30 per cent fat when separated at 100° F. a fat percentage of 45 per cent may be expected from milk separated at 75° F.

Dirt in the bowl. It is obvious that dirt lodged in the cream opening will reduce the cream flow and increase the fat percentage. Obstruction of the skim milk opening will reduce the amount of skim milk and increase the amount of cream, with lower fat tests.

Sometimes separator slime accumulates to such an extent as to close off the passage of skim milk by the edges of the discs and over the divider disc. When this happens, the rate of skim milk flow will be greatly reduced and more cream with lower fat content will be produced.

The amount of flushing. When the last milk has passed into the separator, the bowl is still filled. Part of its content is cream and part skim milk. In order to get all the cream out of the bowl, it is customary to flush with either water or skim milk. In order to force all the cream out of the bowl, enough water or skim milk must be used in flushing to cause a dilution of the cream. The extent of the dilution will depend upon the amount of either skim milk or water used in flushing and the amount of cream separated.

Factors affecting the efficiency of separation. The modern cream separator in good mechanical condition and properly operated is a very efficient machine. The skim milk under good conditions does not contain more than 0.02 per cent and in many cases as low as 0.01 per cent of fat. Under certain conditions the cream separator may become inefficient, and

losses of fat in the skim milk are experienced. The chief factors responsible for inefficiency are as follows:

1. Poor mechanical condition of the separator
2. Too low speed of the bowl
3. Too cold milk
4. Overfeeding
5. Production of too rich cream
6. Dirty bowl

Poor mechanical condition. Poor mechanical condition of the separator may cause inefficiency of separation for a number of reasons. The discs may be so worn as to cause settling in the bowl, resulting in too great space between the divider and the next disc. The divider disc may be so worn that it causes a leak, and the cream and skim milk are remixed. The separator may be so worn in general as to produce vibrations which cause the incoming milk to mix with the separated cream.

Too low speed of bowl. Too low speed of the bowl, obviously, will not produce enough force to separate the cream from the skim milk, resulting in incomplete skimming. This is probably one of the chief reasons for poor skimming of many separators.

Too low temperature of milk. When the temperature of the milk drops below 90° F., fat losses in the skim milk begin. There are two reasons for increased losses of fat with lowered temperatures. Cold milk serum is more viscous than warm serum and, therefore, offers greater resistance to the migration of the fat particles. A second important factor is the fact that the specific gravity of milk fat increases with lowered temperatures to lower the difference between the weight of the fat and the milk serum. In very cold milk with some machines a third factor is present. The cold fat may partially or completely clog the cream outlet to force cream through the skim milk outlet.

Overfeeding. If milk is forced through the bowl too rapidly, it is subjected to the centrifugal force for too short a period to cause complete separation of the fat from the skim milk. Some of the fat particles then pass with the skim milk over the divider disc.

Too rich cream. When the cream screw is turned in to produce too rich cream (60 per cent or above) there is not enough volume going out through the cream opening to accommodate all the fat. Some of the cream then backs up outside of the discs to go out with the skim milk. When exceedingly high fat content cream is desired, it is necessary to slow up the milk inflow to give more time for the centrifugal force to pack the fat in the cream. This is accomplished by the attachments for separators that will produce cream containing up to 80 per cent fat with efficient skimming.

Dirty bowl. If dirt lodges in the cream opening, the cream outlet may be insufficient to accommodate all the fat in the milk, and losses of fat in the skim milk will be experienced. Slime may accumulate on the walls of the bowl to such an extent that the passage for skim milk is completely blocked. Clogging of the bowl in this manner does not cause increased

losses of fat in the skim milk but increases the amount of skim milk going out through the cream outlet. If the bowl becomes completely clogged from the accumulation of slime, all the milk is forced out through the cream outlet, and no skim milk is produced. In this condition the separator functions much like a clarifier.

Sour milk causes rapid clogging of the bowl as well as some losses in fat. Tiny particles of curd enclosing fat particles will pass out with the skim milk.

Effects of mechanical separation. The most obvious effect of subjecting milk to strong centrifugal force is the separation of the fat from the milk serum or skim milk. Because of centrifugal and other forces certain other constituents in milk are forced out of the skim milk to pass either into the cream or into the residue, known as separator slime, in the separator bowl.

Into the cream pass those materials having a lower specific gravity than the milk serum plus certain other substances which are absorbed on the fat particles. Dirt particles of low specific gravity and some microorganisms will pass into the cream because of low specific gravity. The phospholipids, however, although not of low specific gravity, are more concentrated in the cream than in the skim milk; these compounds are adsorbed around the fat globules, whose low specific gravity buoys these heavier materials into the cream.

Separator slime analyzes from 65 to 75 per cent water, 18 to 25 per cent protein, 2.5 to 3.5 per cent ash, and usually less than 3 per cent fat. It consists mostly of leucocytes, bits of coagulated protein, dirt particles, and bacteria, and is also rich in enzymes. The fat present in separator slime is enclosed or adsorbed to heavy material which centrifugal force throws to the outside of the bowl. The leucocytes usually contain much fat. Separator slime also contains appreciable quantities of phospholipids and more bacteria than is found in either the cream or the skim milk. Apparently some bacteria and mold and yeast spores are centrifuged out of the milk. Others that are found in the separator slime adhere to heavier particles and are thrown out with them.

Both the skim milk and the cream may show a larger bacterial count (colonies when grown on appropriate media) than the whole milk from which it is produced. This is accounted for by the forces in separation breaking up the clumps of bacteria in the milk and thus increasing the number of colonies that grow on the cultures. There is no actual increase in the number of bacteria as the result of separation.

COOLING MILK OR CREAM

In the production of milk or cream there is no more important factor than that of prompt and adequate cooling. The rate with which bacteria multiply is dependent upon the temperature of the milk or cream. The data in the following table, taken from New York Circular 10, illustrate the great increase in growth with increased temperatures. For each 5° F. increase in temperature from 40 to 55° F. there is, roughly, a doubling

of the number of bacteria developed over a period of 12 hours. From 55° F. up there is a rapid increase in the rate of multiplication. Milk kept at a temperature of 60° F. develops bacteria approximately 12 times as fast as milk kept at 55° F. At 80° F. bacteria develop more than 1,450 times as fast as at 55° F.

THE RELATION BETWEEN TEMPERATURE AND BACTERIAL DEVELOPMENT OF MILK DURING 12 HOURS

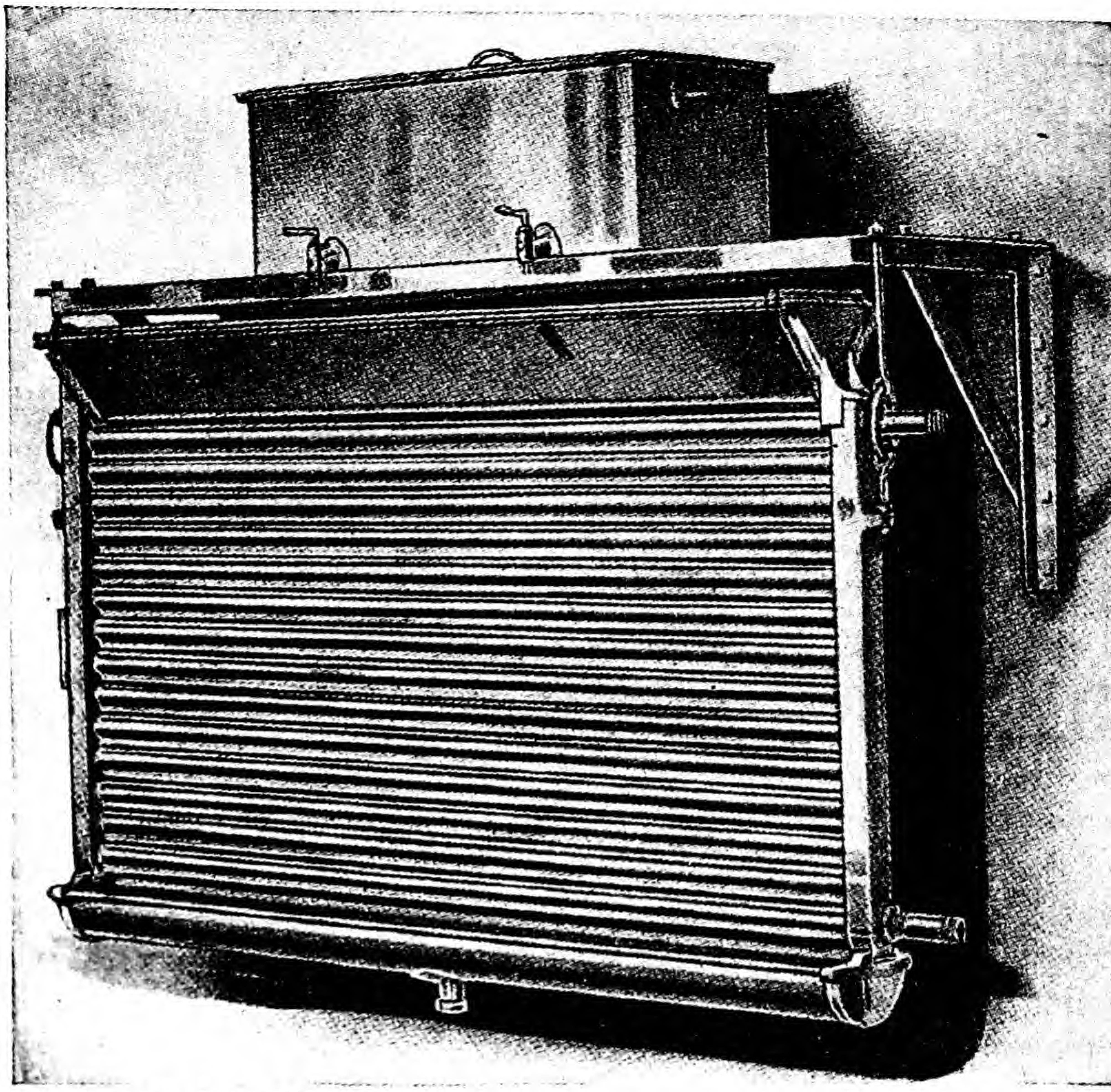
Temperature: Degrees F.	Bacteria per cc. after 12 hours
40	4,000
45	9,000
50	18,000
55	38,000
60	453,000
70	8,800,000
80	55,300,000

To avoid rapid bacterial growth and resulting deterioration of milk or cream, these products should be promptly cooled to 50° F. or lower and kept at that temperature. Milk or cream may be cooled by running it over surfaces cooled by running water or brine, by setting it in cold water, by immersing it into the milk coils in which cold water or brine circulates, or by placing it in a chamber or cabinet where the air is cooled.

Surface coolers. The surface coolers are the most efficient from a standpoint of rapidity of cooling, provided the cooling medium is cold. The milk may be brought to within 5° F. of the temperature of the cooling medium in a few seconds. Where artificially cooled water or brine is used the coolers may be divided into two sections. In the upper section is circulated natural water to partially cool the milk, while the cold brine or water is circulated through the lower section to complete the cooling process. The surface coolers also help drive off certain odors. Unless these coolers are carefully cleaned and sterilized they may be a source of bacterial contamination of the milk. (Fig. 127.)

Cooling tanks. Milk and cream are most commonly cooled in cans placed in tanks of cold water which may be cooled by ice or artificial refrigeration. The most economical cooling is done where water of 50° F. or below can flow continuously through the cooling tank. Many have arranged for the well water or spring water to pass through the cooling tank before running into the watering tank for the stock.

Milk or cream is not cooled so rapidly by this method as by the surface coolers; but if cold water is passed through the cooling tank, this method is satisfactory, provided the milk or cream is placed in the tank immediately after being produced. A number of mechanical devices have been developed to stir the milk or cream while cooling. These devices speed up the cooling process, as milk that is stirred cools more rapidly than milk that is not stirred. In experiments at the New York Station when milk



Creamery Package Mfg. Co.

Fig. 127. A surface milk cooler. The milk flows in thin sheets over the surface, and cold water or brine circulates inside the tubes.

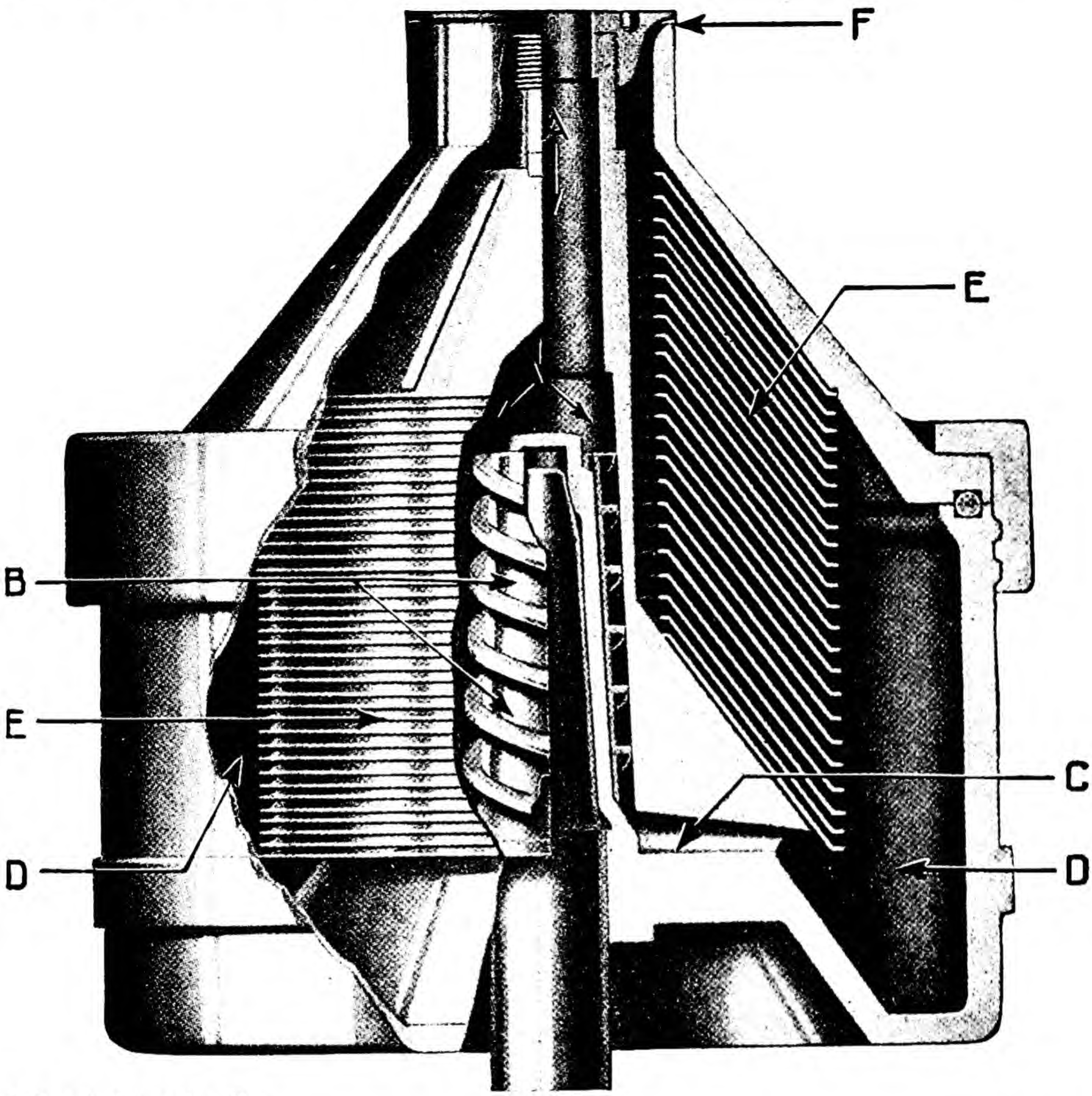
in cans was set in ice water, at the end of one hour the following temperatures were observed: when not stirred, 61.2° F.; when stirred every 5 minutes, 52.6° F.; when stirred every 10 minutes, 53.5° F.; and when stirred continuously, 45.3° F. In addition to the fact that there is labor involved with the use of stirring devices, they meet with objection on the ground that they are a source of bacterial contamination.

Immersion into the can of cooling coils through which cold water or brine circulates is but little more efficient in cooling than merely setting the cans in a tank of comparably cold water. Furthermore, these devices meet with the objection that when they are used the containers cannot be completely filled, and that they are a source of contamination.

Cooling in cold air chambers is increasing in popularity. Air is not so efficient as water in cooling, unless it is rapidly circulated; cold air chambers, particularly the "walk in" type, are more convenient.

CLARIFICATION AND FILTRATION OF MILK

In order to remove more of the dirt from milk than can be done by strainers, one of two processes—clarification or filtration—is resorted to by



DeLaval Separator Co.

Fig. 128. Cross section of a clarifying bowl showing the passage of the milk down through the tube at *A*, its course through the bowl (*B*, *C*, *D*, and *E*), and finally its exit at *F*. The impurities are collected in the large space at *D*.

milk plants. Clarification consists of passing milk through a centrifuge, known as a clarifier, that resembles a cream separator. It differs from the separator in that there is but one exit, where the cream and milk are thoroughly mixed. The bowl of the clarifier also has a greater capacity for holding dirt than has the bowl of the separator. In clarification the material with a higher specific gravity than the milk serum is thrown out and collected in the clarifier bowl. (Fig. 128.) This material is like separator slime in all respects. Clarified milk does not keep any better than nonclarified milk. While many bacteria are removed in the slime, other colonies are broken up so as not to reduce the bacterial count by the culture method.

Many milk plants use filters instead of clarifiers to remove the visible

dirt from market milk. The filter consists of a fine meshed cloth material fixed in a mechanical device so that the milk is forced through by pressure. All the coarser particles are filtered out regardless of the specific gravity. The leucocytes and cell debris that are centrifuged out by the clarifier are not removed by the milk filter.

PASTEURIZATION

Definition. Pasteurization refers to treating milk with heat in such a way as to destroy nearly all the bacteria and all of the pathogenic bacteria. The term is derived from the name of Louis Pasteur, who found that heating wine to 140° F. (60° C.) greatly improved its keeping qualities through destroying most of the bacteria. Milk may be pasteurized by two methods—holding or flash. The temperature at which and the time that milk must be held to qualify as being pasteurized is specified by law and by milk ordinances.

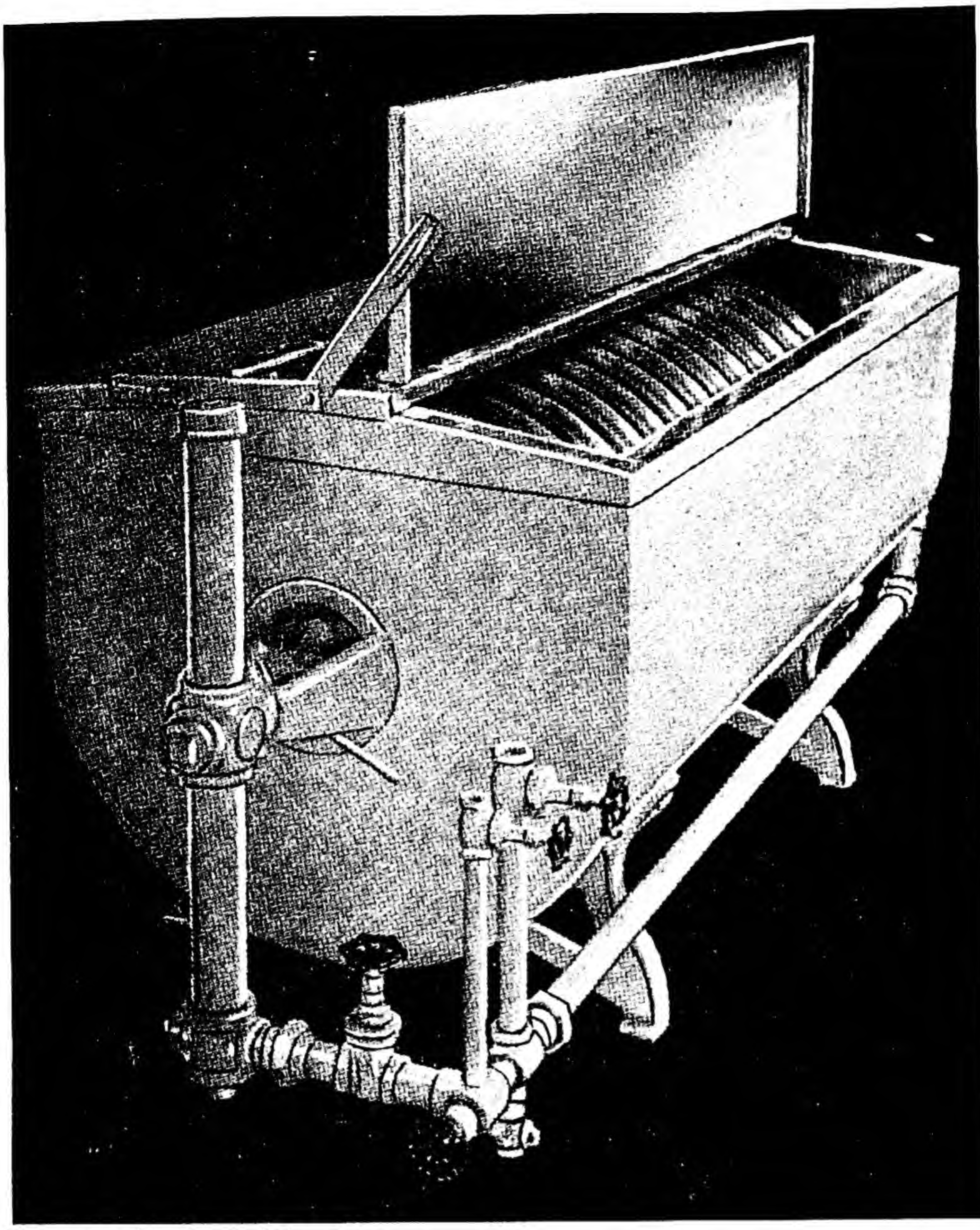
Holding process. According to the United States Department of Agriculture, milk, to be pasteurized by the holding process, must be heated to 145° F. (62.8° C.) for 30 minutes. The United States Public Health Service accepts milk as being pasteurized when held at 142° F. (61.11° C.) for 30 minutes. As the lower temperature has less effect upon the characteristics of the milk it is customary to pasteurize milk at 142 to 143° F. Some states and municipalities, however, require pasteurization at 145° F. Following heating, the product must be cooled rapidly.

Flash process. Heating milk at 165 to 180° F. (73.9 to 82.2° C.) for but a few seconds followed by rapid cooling has essentially the same effect that holding at 142 to 145° F. has, and is known as the flash process. This method has not been used extensively because of lack of equipment that is sufficiently reliable. More recently developed flash pasteurizers are proving satisfactory. In the past there have been three main objections to flash system. Public health officials have not been too well convinced of its reliability; frequently the cream line of the milk pasteurized by this method is lowered; and sometimes a cooked flavor is imparted to both milk and cream.

Holding process equipment. For the holding process milk may be pasteurized in different types of equipment: in vats equipped with rotating coils, in glass-lined tanks, in spray vats, and in the bottle.

Coil vats are the most common type of pasteurizer. This type consists of a well-insulated rectangular tank in which a revolving hollow coil carries the heat to the milk. The coil serves three purposes: it carries the hot water which heats the milk; it agitates the milk; and when the holding time is up it serves to cool the milk when cold water is passed through the tubes. (Fig. 129.)

Glass-lined tanks differ from coil vats in that the heat is applied to the wall of the tank from hot water or steam which is held there by an outer jacket. An agitator keeps the milk stirred during the heating and cooling processes. Cooling is effected by replacing the hot water in the jacket with



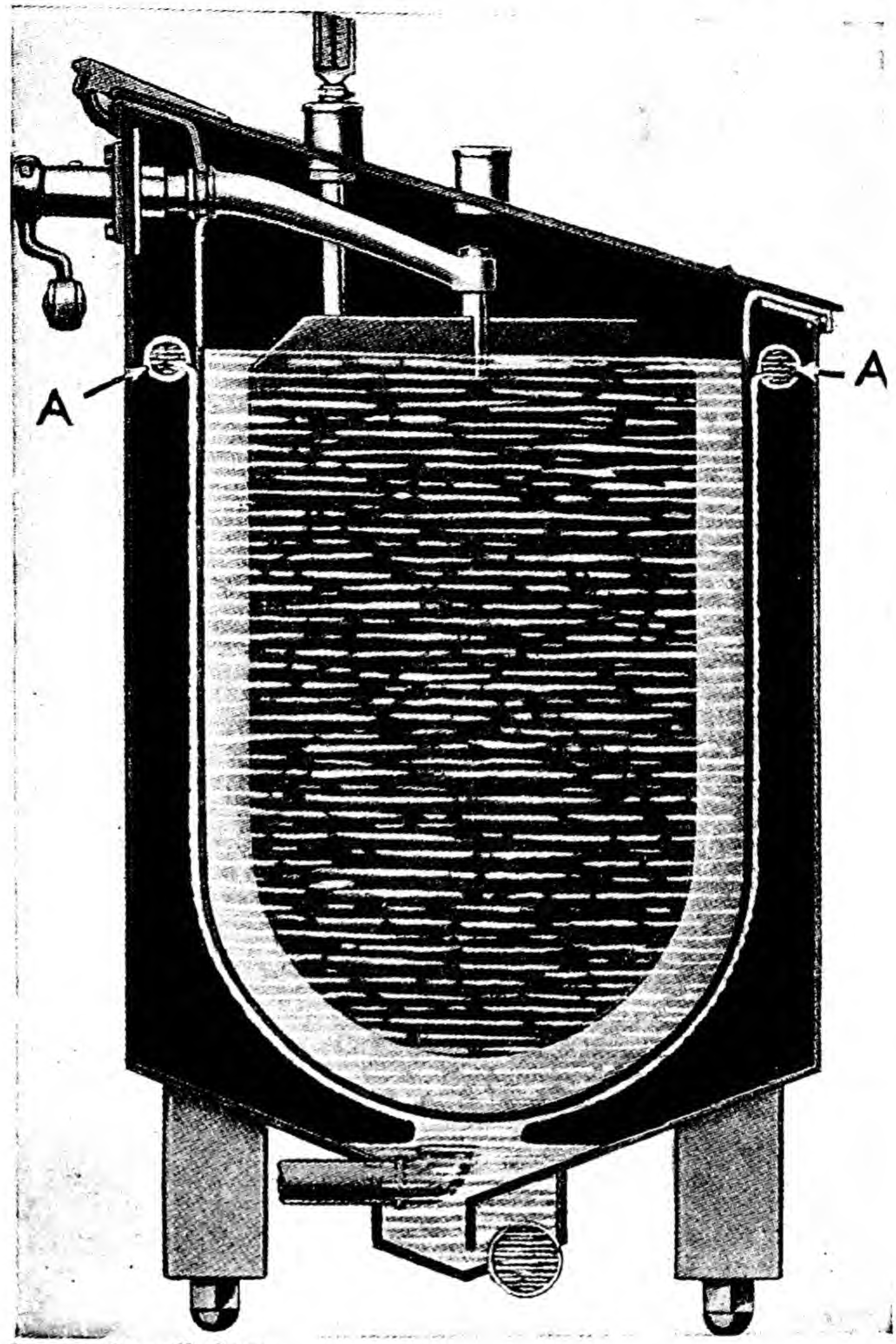
Creamery Package Mfg. Co.

Fig. 129. A coil vat pasteurizer showing the coils through which the hot water is passed to heat the milk. Following pasteurization cold water may be passed through the coils to cool the milk.

cold water. This type gets its name from the fact that it is constructed of steel and lined with glass.

Spray vats are long, deep vats equipped with an apparatus in the outer jacket for spraying water against the inside walls. The milk or cream in the vat is agitated slowly by paddles that sway back and forth. Cooling is effected by spraying cold water against the sides of the inner vat. (Fig. 130.)

In the bottle pasteurization. Milk or cream may be pasteurized in the bottle by two methods. The bottles may be placed in a chamber where the temperature may be brought up to the required height for the proper length of time; or special bottles using metal caps may be immersed in a water bath of the right temperature for the required length of time. In



Cherry-Burrell Corp.

Fig. 130. Cross section of a "spray type" pasteurizer. Note the inlet at *A* of hot water which flows down the lining, and also the paddle which causes rapid flow of the milk against the heated sides of the pasteurizer.

either case cooling is done by gradually changing the temperature of the environment.

Flash pasteurization equipment. There are several types of flash pasteurizers using steam, hot water, or electrically heated plates for heating. Regardless of the mechanical device for heating, the principle involved is that of getting the milk in a thin film against the heated surface. This may be accomplished by two tubes, one inside the other; the hot water or steam is passed through the inner tube, and the milk is passed between the outer and inner tube. Two drums, one within the other, and both heated with steam or hot water, from another type in which the milk is heated

by passing in a thin film between the two drums. One of the most efficient machines of this type is known as the plate type pasteurizer. This consists of a series of plates held together in a press and so constructed as to form two separate continuous passages. When operating, hot water is passed in one direction and milk in the other.

Cooling flash pasteurized milk. On account of the high temperatures used in flash pasteurization, a rapid cooling system must be used or cooked flavors and poor cream lines will be experienced. The milk should, therefore, pass directly from the pasteurizer to a cooler, preferably the tubular type where two tubes, one inside the other, are used. The milk is passed through the inner tube and the cooling medium is the space between the two. The plate type of flash pasteurizer is also most efficient cooler when cold water is used in place of hot water.

Effect of pasteurization on milk. When milk is properly pasteurized, about 98 to 99 per cent of all bacteria are destroyed. Experiments have shown that pathogenic organisms such as those producing typhoid fever, tuberculosis, diphtheria, etc., are all destroyed in properly pasteurized milk. Yeasts and molds are also mostly destroyed. Some heat resistant organisms that are not known to be harmful are not destroyed.

Some of the enzymes are completely or partially destroyed by pasteurization. This fact forms the basis for the only fairly reliable test for pasteurization. As phosphoesterase is destroyed by thorough pasteurization, a test for its presence is now regarded as the best test for pasteurized milk.

Vitamin C is usually mostly destroyed by pasteurization, not so much from the temperature as from oxidation.

There are probably some minor effects of pasteurization upon some of the other constituents of milk, but they are so slight that they are insignificant, except for the effect upon the cream line. When milk is pasteurized for 30 minutes at not over 143° F., and then is immediately cooled while vigorously agitated, there is no effect upon the cream line. If, however, milk is not cooled immediately following pasteurization, or is not vigorously agitated while still warm, or is heated at higher temperatures than 143° F., the cream line will be materially reduced.

HOMOGENIZATION

Homogenization is the forcing of a product through a small opening under high pressure. Special machines built for this are known as homogenizers. Pressures of from 2,500 to 5,000 pounds per square inch are applied. As a result the fat is broken up into small fragments and the physical properties of the milk or cream greatly changed. Homogenization is the most effective at pasteurization temperatures, when about 80 per cent of the fat particles are less than 2 micra in diameter. They are so small that they will not rise to the surface in milk. Homogenized cream will not churn because of the smallness of the fat particles.

The viscosity of the homogenized product is greatly increased. This is usually believed to be due to a rearrangement of the protein adsorbed on the fat globule. Good homogenization divides the fat globules 1,000 or

more times and increases the surface area of the fat by 100 or more times. There is, therefore, a greatly increased surface of the proteins adsorbed to the fat particles.

Homogenized milk or cream to be sold must be labeled as such. Homogenization is also commonly used in reconstituting milk or cream from butter oil with skim milk or milk powders.

OTHER PROCESSES

There are, in addition to those treated in this chapter, many other processes used. The more important of these processes will be taken up in the following chapters, in the treatment of the various subdivisions of the dairy industry.

Chapter 50

MARKET MILK

Market milk is the term applied to milk that is sold to the consumer in fluid form. About 42 per cent of all milk produced in the United States is consumed as fluid milk. Thirty per cent is sold as market milk in villages and cities, and 12 per cent is consumed on farms. It has been estimated that the services of from 900,000 to 1,200,000 people are required in the production, transportation, processing, and distribution of milk sold as market milk.

Milk is highly perishable and an excellent medium for harboring a number of different disease producing organisms. The production and processing of this product for fluid consumption has developed into a very highly specialized industry. The general economic features of market milk production as well as the economics of consumption have been discussed previously. At this point the general technical features of market milk will be considered. For discussion the subject lends itself to division into the following subheads:

1. Kinds of market milk
2. Production on the farm
3. Transportation
4. Processing and distribution
5. Health supervision

Kinds of market milk. Market milk may be divided into two classes—pasteurized or raw. Under both of these classes are a number of types of milk depending upon the conditions under which it has been produced or some special features of the product.

Classified on the basis of the conditions under which market milk is produced, there are certified milk, grade A milk, and grade B milk. These milks may be either raw or pasteurized. In recent years a number of special milks have appeared upon the market. Among the more widely sold of these are special brands, such as high testing milks like "Golden Guernsey" and "Jersey Cream Line." Other special milks are based upon low curd tension, high vitamin D content, and high vitamin A content.

Production of market milk on the farm. The location and adaptation of dairy farms for the production of market milk have been discussed previously. Here will be considered the special features required for the production of suitable market milk on the farm. Besides entailing all the features required for successful dairying, the production of market milk requires that special attention be paid to keeping healthy cows, and that suitable housing, the right kind of equipment, and sanitary methods be used. (See score card, page 595.) All of these are necessary for good dairying of any kind, but are absolutely essential for market milk production.

Healthy cows. All milk ordinances or milk laws state that the cows must be free from any disease before their milk will be acceptable for market milk. Not only must they appear to be in good health, but they must also be free from those diseases which are discerned by tests, such as tuberculosis, Bang's disease, Johne's disease, and mastitis.

Feed and water. The feed that is fed the cows must be clean and pure. Decayed, musty, or otherwise spoiled feeds as well as feeds considered poisonous must not be fed cows producing market milk. Many feeds impart special flavors and odors to milk, giving considerable concern to both the producer and distributor of milk.

The drinking water, likewise, should be clean and free from pollution. Cows should not be permitted to drink from stagnant ponds or pools into which polluted water drains.

Housing. Milk ordinances and score cards provide that the stables be constructed of materials that can easily be kept clean. Floors, walls, ceilings, and all appurtenances should be of such construction that they will not accumulate dirt and can easily be washed. Stables must be well lighted; at least 4 square feet of glass per cow must be provided in windows. Ventilation of the dairy barn for market milk production is also an important item. Not only must acceptable barns be provided with ventilation facilities, but there must be evidence that the ventilation functions. The yards must be well drained and of such material as not to become muddy.

A suitable milk house must also be provided. Different market milk centers have different requirements for acceptable milk houses. In general, the milk house must be separate from the barn; if it is not, there must be a well-ventilated corridor with a self-closing door at each end between the milk house and the barn. The milk house should be of two compartments (some markets require three), one where the milk is handled and the other where the utensils are cleaned. When a third room is required it houses the boiler and power equipment.

Equipment. In order to produce high quality milk it is essential to have the proper equipment. In the barn the important equipment is that equipment used for milking. If cows are milked by hand, nothing but small-topped pails should be used. Only a fraction of dirt falls into the small-topped pail that falls into the ordinary pail. The equipment with which milk comes in contact should be in perfect condition. Dented, cracked, or badly worn equipment has excellent places for harboring bacteria.

The milk house or room should be furnished with the proper strainers, efficient coolers, separators, and cold storage facilities. The wash room must have an ample supply of both hot and cold water and steam. Two compartment wash tanks are also needed—one for washing and the other for rinsing. Ample drying racks for milk cans, pails, and other equipment must also be provided. It is desirable that a steam jet be provided to sterilize cans, pails, and other equipment.

Sanitary methods. While proper equipment is desirable and even essential to producing clean, wholesome milk, the methods employed in the production of milk are of far greater importance. A person who observes all the rules of cleanliness will produce cleaner milk in poorly constructed barns with poor equipment than will a person who is careless in ideal buildings with perfect equipment.

Clean milk production begins with clean and healthy milkers and caretakers. No person who is afflicted with any communicable disease should be permitted to handle milk. While the wearing of white suits is not essential to clean milk production it adds much to the appearance and personal pride of the milkers.

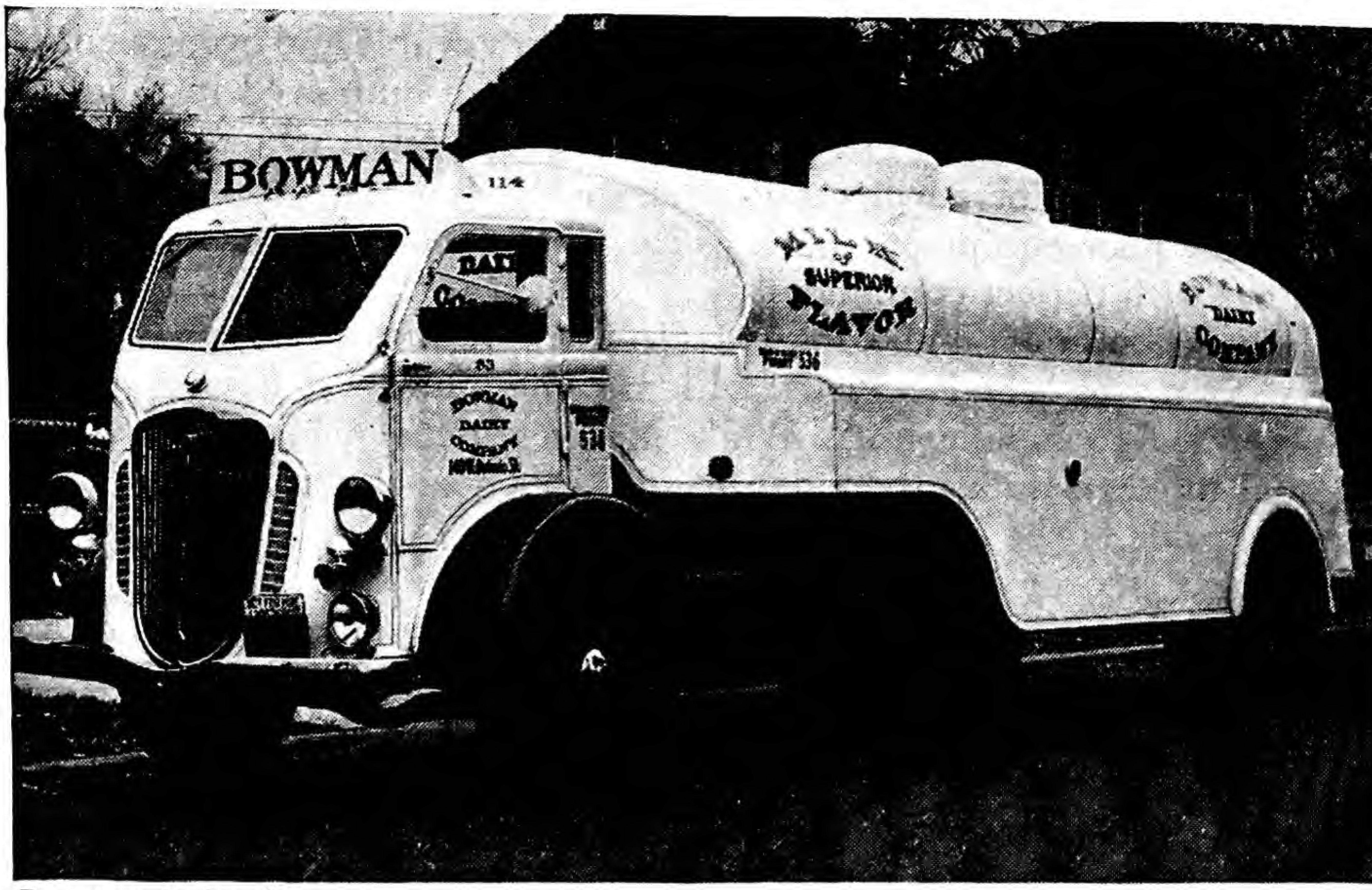
The next step in clean milk production is clean cows. This requires that the stables and yards be kept clean, and that an abundance of clean bedding be used when the cows are housed in the stable all day. During the day, when the cows are out except at milking time, the barn and stall floors should be washed down with a hose. Before the cows are milked, their udders should be washed and dried.

Milking should be done with dry hands. Wet hand milking is the cause of the worst bacterial contamination of milk and must not be tolerated. The hands should be washed after the milking of each cow.

Next in importance to the cleanliness in milking is the cleanliness of the utensils with which milk comes in contact. All pails, milking machine parts, cans, coolers, strainers, and any other parts or utensils with which milk comes in contact must be thoroughly cleaned and sterilized after each use. Cleaning is facilitated by rinsing the utensil with cold water immediately after it is used. Next it should be thoroughly scrubbed with warm to hot water to which is added a good washing powder, a good stiff-bristled brush being used. After the washing solution is rinsed off, the equipment should be subjected to sterilization either by the chemical or heat treatment methods. If chemicals are used, the directions furnished by the manufacturer should be followed explicitly. If heat treatment is used, subjection to live steam is the most efficient. Next is the subjection to boiling water. Following the treatment the utensils should be inverted to drain and dry.

Milk should be removed from the barn to the milk room immediately after it is drawn to avoid absorption of barn odors. In the milk room it should be strained and poured over a suitable cooler so that it will be cooled to below 50° F. within 5 to 10 minutes after being drawn from the cow. It should then be stored in a cold storage of either water or the cold air types that will keep the temperature below 50° F.

Certified milk. Milk produced under the conditions specified above will grade A. To produce certified milk much more rigid regulations must be followed. Certified milk is produced under the most rigid supervision to conform with regulations laid down by the Medical Milk Commission, a part of the American Medical Association. The object of certified milk is the attainment of the highest quality and purity in milk that is possible.



Bowman Dairy Co.

Fig. 131. A modern milk tank truck unit, used in transporting milk from the country receiving stations to the processing plant.

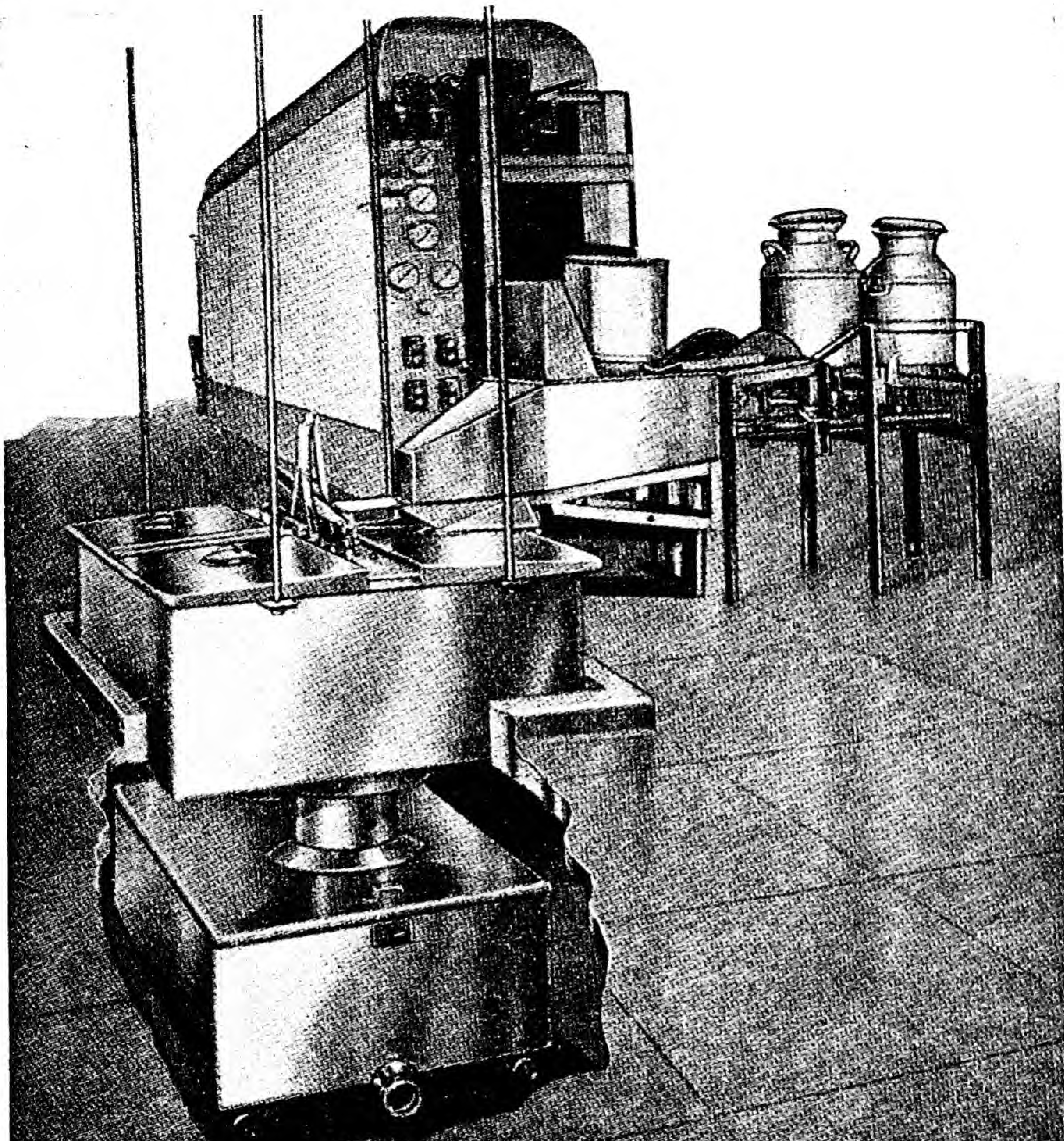
While most certified milk is sold raw it may be pasteurized to add still further to its safety.

Transportation of milk. Market milk is transported varying distances, depending upon the location of the farm upon which it is produced. In many cases the producer delivers the milk to the processing plant; in other cases the milk must be hauled great distances by truck or train. Even when the producer is located near the market, the milk is frequently picked up by commercial hauling trucks.

For short distance hauling the milk is usually handled in 10 gallon cans. For long distance hauling it may also be handled in cans whether shipped by truck or by rail, but an increasing amount of milk shipped for long distances is carried by specially constructed tanks. These tanks are glass-lined, tinned, or made of stainless steel, and are thoroughly insulated. Tank cars may have a capacity of 50,000 pounds of milk. (Fig. 131.)

The problems in milk transportation are to get the milk to the market as soon as possible after it is produced, and to avoid temperature increases in warm weather or freezing in cold weather. The insulated truck tanks or tank cars will carry milk for hundreds of miles without any appreciable increase in temperature. Milk hauled by trucks must be protected by the proper blanketing in cold weather and icing in warm weather.

Processing and distribution. After milk is produced on the farm, the methods of getting it to the consumer vary. In small towns nearly all the milk is distributed by the producer. In larger towns and cities varying proportions of the milk are distributed by the producer and large milk



Lathrop-Paulson Co.

Fig. 132. A milk receiving compartment, showing dump tank, weigh can, receiving tank, and can washer.

distributing concerns. As yet the greater part of the milk distributed by the producer is sold as raw milk, while the milk processed in large plants is pasteurized before it is sold. Many dairymen distributing their own product also pasteurize their own milk, but the cost of the necessary pasteurizing equipment and operating costs are too high for small-scale production.

Milk plant. The modern milk plant consists of a receiving department, a room for filtering or clarifying, and pasteurization, bottling machines, cold storage rooms, and usually a control laboratory. (Fig. 132.)

The milk is usually received and weighed in a special room. Here the cans may be washed and returned to the trucker. From this room it is pumped to storage tanks, from which it passes through a clarifier; or it may be filtered before being pumped into the pasteurizers. The milk is

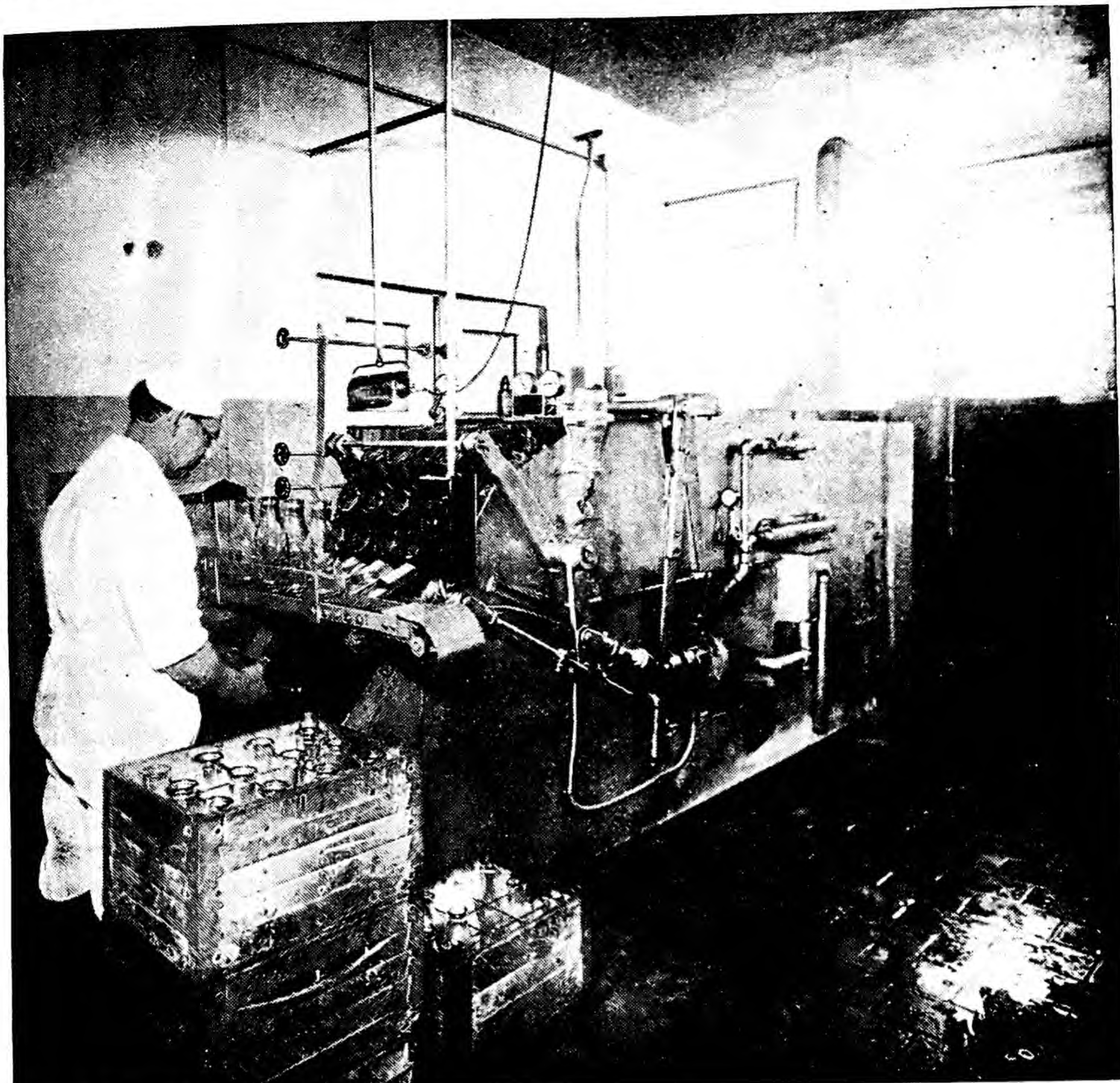
Cherry-Burrell Corp.

Fig. 133. A corner of a modern milk plant showing pasteurizers (spray type), milk cooler, and bottling machine.

either cooled in the pasteurizer or is passed over coolers, and then it goes into the bottling machine. (Fig. 133.) From the bottling machine the milk is taken to coolers where it is kept until loaded out on the wagon. Each modern plant is also equipped with large automatic bottle washing machines where returned bottles are washed. (Fig. 134.)

Delivery to the consumer. One of the most expensive operations in the while procedure of marketing milk is that of delivery to the consumer. The cost for delivery varies greatly in the different localities, depending upon the size of the load carried and the wages paid the drivers. The wagons usually carry cream, buttermilk, and butter in addition to milk. The load is usually determined in units equivalent to one quart. The following are considered as one quart point: 1 quart or 2 pints of milk, ½ pint cream, 1 quart buttermilk, or 1 pound butter.

The loads per wagon vary from 240 quart points to as high as 400 or even 550 quart points average per city. Duplication of routes where as

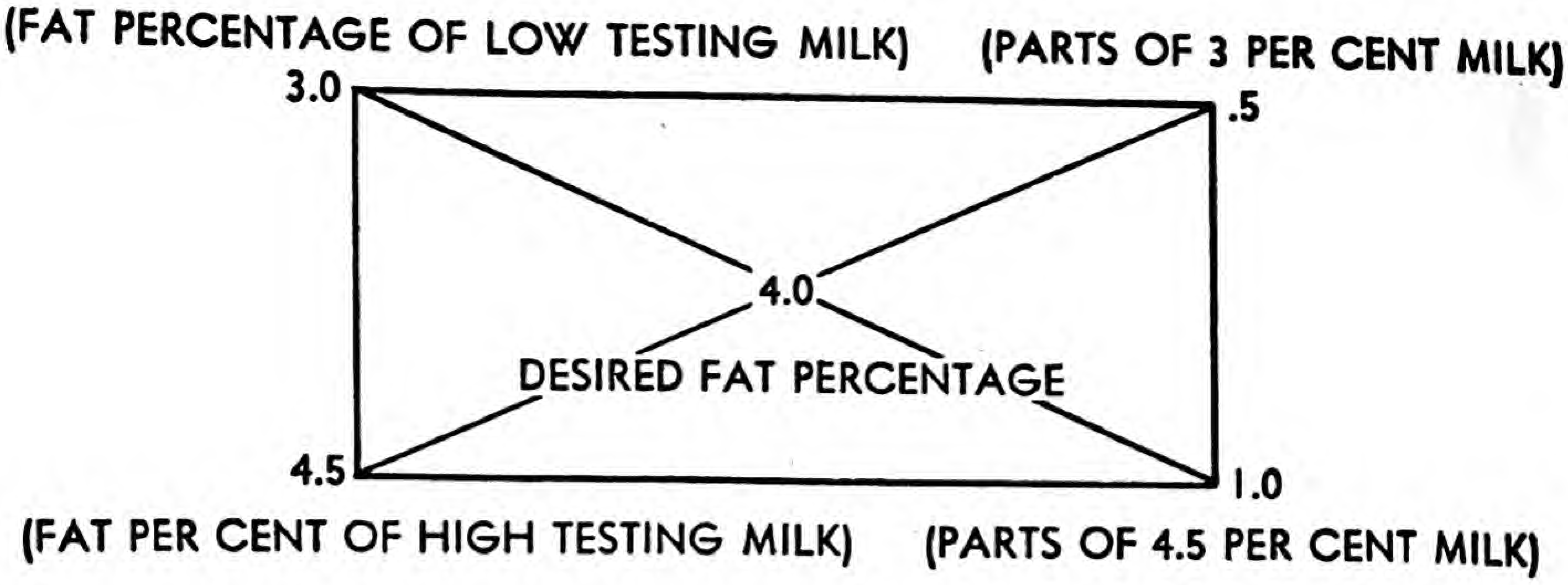


Cherry-Burrell Corp.

Fig. 134. A modern milk bottle washer.

many as a dozen or more wagons pass on the same streets is responsible for lowered efficiency and increased cost in milk distribution.

Standardization of milk. In nearly all large milk plants the milk is standardized to the fat content specified by law or ordinance, or otherwise agreed upon as the fat percentage for market milk. The milk is standardized by adding richer milk or cream if the milk is too low in fat content. If the milk is too high in fat, it is standardized by the addition of lower testing milk or skim milk. The amount to be added is readily determined by the Pearson square. By this method a square or rectangle is constructed. In the center is placed the desired fat percentage, here assumed to be 4.0 per cent. In the upper left-hand corner is placed the fat content of one milk and in the lower left-hand corner the fat content of the other milk to be mixed. The differences in the desired fat content and the fat content of the two milks to be mixed are placed in the opposite corners of the rectangle. These values represent the relative amounts of the two milks



that must be mixed to obtain the desired fat content. In the example given, mixing 0.5 pounds of 3.0 per cent milk with 1 pound of 4.5 per cent milk makes a milk testing 4.0 fat.

Supervision of market milk. No other food product comes in for closer and more thorough supervision by the health authorities than does the production and distribution of market milk for large cities. This is because milk is so universally used and may be the source of disease producing organisms, and also because its character lends itself to such fraudulent practices as the removal of part of the fat, the addition of water, and several other like practices.

Supervision begins upon the farm, which must be equipped with the necessary and satisfactory buildings and equipment before the milk is acceptable for market. Frequent inspections are then made for the health of the cows and of the milkers and other milk handlers, as well as the general methods used in production. Samples of milk are taken for chemical and bacterial analysis, including sediment tests.

The milk processing plants are also inspected frequently for the condition and practices of the plant. Faulty equipment is condemned and must be replaced. The temperature charts of the pasteurizer are watched that pasteurization is properly done. Samples of the milk are taken frequently from the milk wagons to be analyzed for purity and wholesomeness.

The success of the inspection system is attested to by the relatively rare appearance of disease that is milk borne. The value of close supervision of milk production and distribution for fluid consumption is universally recognized, and many small communities are adopting close inspection systems.

Score card for market milk production. The necessity for adequate and proper housing and equipment for the production of high quality milk has been recognized, and score cards have been adopted for inspectors to use in rating the producers. Out of a total of 100 points allowed for perfection 40 points are for the barn and milk room construction and equipment, and 60 points are for the methods in caring for the cows, stables, milk room, utensils, milking, and handling the milk. (See next two pages.)

Score Card for Market Milk Production

Equipment		Score Perfect	Score Allowed
Cows			
Health		6	....
Apparently in good health	1		
If tested with tuberculin within a year and no tuberculosis is found, or if tested within six months and all reacting animals removed	5		
(If tested within a year and reacting animals are found and removed, 3.)			
Food (Clean and wholesome.)		1	....
Water (Clean and fresh.)		1	....
Stables			
Location of stables		2	....
Well drained	1		
Free from contaminating surroundings	1		
Construction of stables		4	....
Tight, sound floor, and proper gutter	2		
Smooth, tight walls and ceiling	1		
Proper stall, tie, and manger	1		
Provision for light: 4 sq. ft. of glass per cow		4	....
(Three sq. ft., 3; 2 sq. ft., 2; 1 sq. ft., 1. Deduct for uneven distribution.)			
Bedding		1	....
Ventilation		7	....
Provision for fresh air, controllable flue system	3		
(Windows hinged at bottom, 1.5; sliding windows, 1; other openings, 0.5.)			
Cubic feet of space per cow, 500 feet	3		
(Less than 500 feet, 2; less than 400 feet, 1; less than 300 feet, 0.)			
Provision for controlling temperature	1		
Utensils			
Construction and condition of utensils		1	....
Water for cleaning (Clean, convenient, and abundant.)		1	....
Small-top milking pail		5	....
Milk cooler		1	....
Clean milking suits		1	....
Milk Room or Milk House			
Location: Free from contaminating surroundings		1	....
Construction of milk room		2	....
Floor, walls, and ceilings	1		
Light, ventilation, screens	1		
Separate rooms for washing utensils and handling milk		1	....
Facilities for steam (Hot water, 0.5.)		1	....
Total		40	

Score Card for Market Milk Production (*Contd.*)

Methods		Score Perfect	Score Allowed
Cows			
Clean		8	....
(Free from visible dirt, 6.)			
Stables			
Cleanliness of stables		6	....
Floor	2		
Walls	1		
Ceilings and ledges	1		
Mangers and partitions	1		
Windows	1		
Stable air at milking time		5	....
Freedom from dust	3		
Freedom from odors	2		
Cleanliness of bedding		1	....
Barnyard		2	....
Clean	1		
Well drained	1		
Removal of manure daily to 50 feet from stable		2	....
Milk Room or Milk House			
Cleanliness of milk room		3	....
Utensils and Milking			
Care and cleanliness of utensils		8	....
Thoroughly washed	2		
Sterilized in steam for 15 minutes	3		
(Placed over steam jet, or scalded with boiling water, 2.)			
Protected from contamination	3		
Cleanliness of milking		9	....
Clean, dry hands	3		
Udders washed and wiped	6		
(Udders cleaned with moist cloth, 4; cleaned with dry cloth or brushed at least 15 minutes before milking, 1.)			
Handling the Milk			
Cleanliness of attendants in milk room		2	....
Milk removed immediately from stable without pouring from pail		2	....
Cooled immediately after milking each cow		2	....
Cooled below 50° F.		5	....
(51 to 55°, 4; 56 to 60°, 2.)			
Stored below 50° F.		3	....
(51 to 55°, 2; 56 to 60°, 1.)			
Transportation below 50° F.		2	....
(51 to 55°, 1.5; 56 to 60°, 1.)			
(If delivered twice a day, allow perfect score for storage and transportation.)			
Total		60	

Chapter 51

BUTTER

THIS DISCUSSION WILL DEAL WITH THE FUNDAMENTALS INVOLVED IN THE manufacture of butter, beginning with a consideration of the composition and legal standards. This will be followed by a consideration of the principles of churning and the factors that influence churning, and of the handling of the butter following churning. And, since one's knowledge of the manufacture of butter would not be complete without information regarding the kinds and grades of butter, the defects of butter, the cream used and its treatment, the tests used, and the by-products, a brief discussion of these points will follow that of churning and working butter.

COMPOSITION AND LEGAL STANDARDS

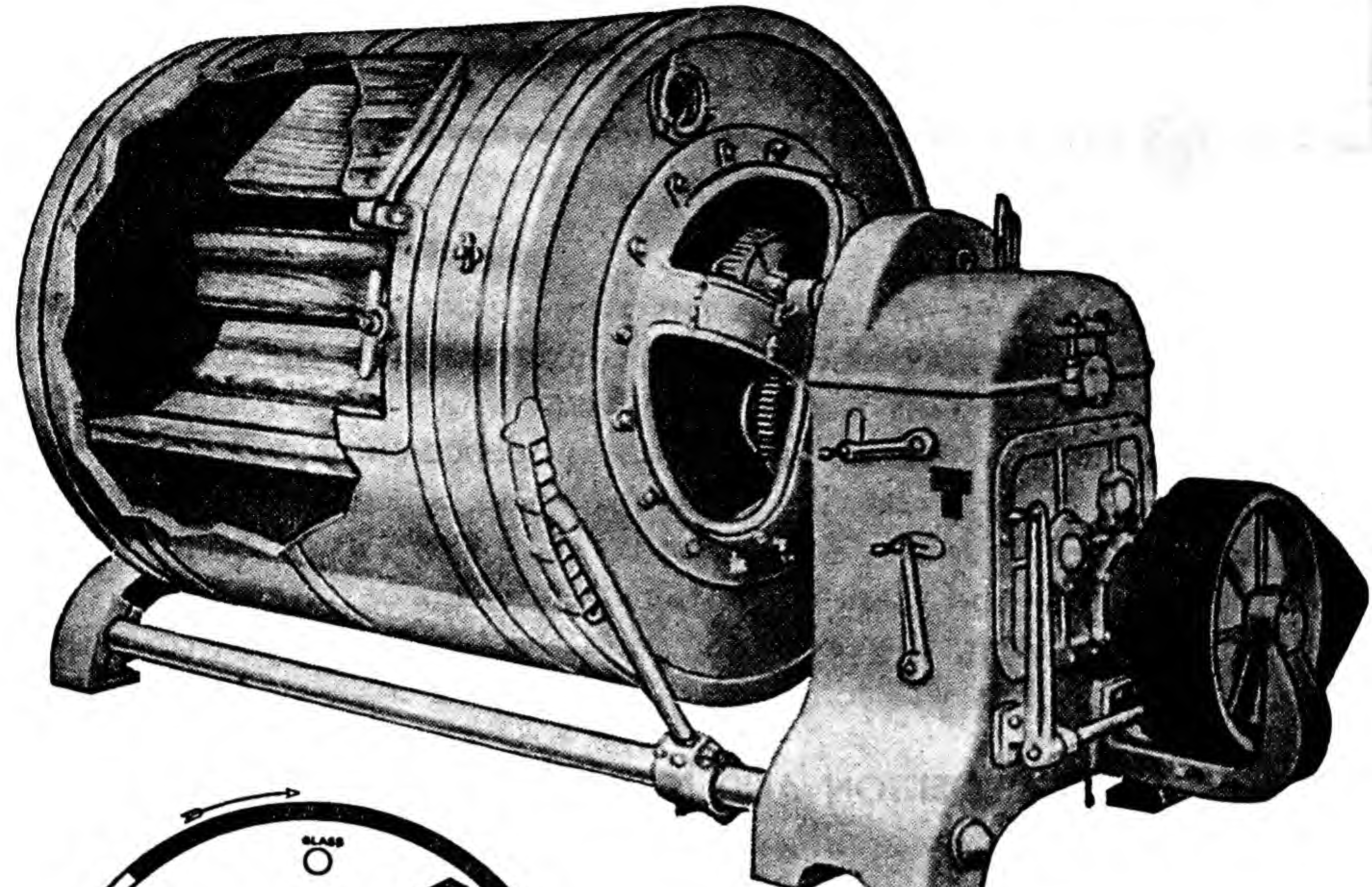
Butter consists mainly of the fat of milk agglomerated by adequate agitation of the cream or milk. In the agglomerated mass of fat particles, however, some of all the ingredients of milk are distributed, as well as any salt that may be added. The relative amounts of the constituents of butter vary greatly, depending upon the conditions under which it is made.

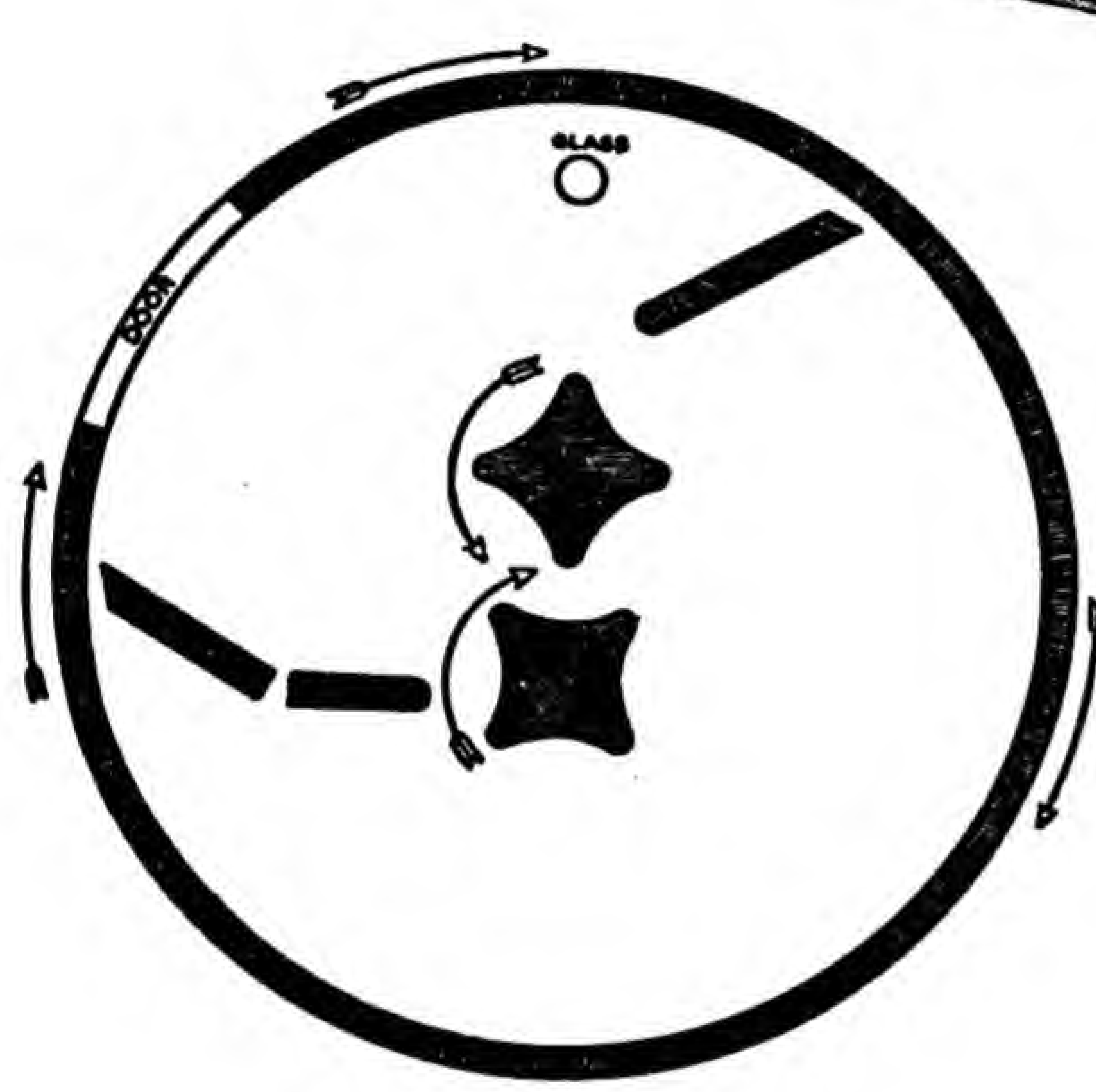
The fat content of butter averages about 82 per cent and normally varies between 80 and 84 per cent. The water content averages about 15 per cent and varies from 14 to 16 per cent. Salt averages about 2.5 per cent and varies from .0 to 4.0 per cent. Curd averages about 1 per cent and varies from 0.1 to 3.5 per cent. In addition to these there are small amounts of lactose, milk, and ash, and traces of other constituents, such as the phospholipids and fat soluble materials. Among the latter carotene and artificial butter color are the most important.

Because of the great variability in the composition of butter and the possibilities of fraudulent practices by lowering the fat content by various means, legal minimum standards for fat and maximum standards for water have been set. According to the Federal requirements, butter must contain not less than 80 per cent of fat and not more than 16 per cent of water. This is usually referred to as the double standard.

Because of the double standard it is difficult to make unsalted butter with as low as 80 per cent of fat. As a result, unsalted butter as a rule contains about 2 per cent more fat than the salted product.

Structure of butter. In milk the fat is present in an emulsion in which the fat is the dispersed phase and water is the continuous phase. Butter is also an emulsion, but it is reverse from that of milk or cream. In butter the fat is the continuous phase and the water is dispersed in the fat in the form of tiny droplets. In some butters, at least, water may be present in a fairly continuous phase in thin sheets between large particles of butter.





Creamery Package Mfg. Co.

Fig. 135. Cutaway view and diagrammatic cross section of a combined churn and worker, showing position of shelves and worker rolls and the way butter is worked.

This is particularly true in poorly worked butters, where water may appear in large drops to produce the condition known as "leaky." The curd, salt, and milk constituents present in butter are either dispersed or in solution in the water.

Butter is, therefore, a fairly complicated structure in which a colloidal and true solution of materials in water is emulsified in fat.

CHURNING

Principles of churning. Churning, the term used for the production of butter from cream or milk, is the process by which the highly dispersed fat particles are brought together to form larger aggregates. The amalgamation of the fat particles is effected by the concussion caused by the churning process. While there is some controversy as to the exact way in which butter is formed, the preponderance of opinion is that the fat particles unite through the force of impact with one another due to the churning action. In this way two fat globules unite to form one larger

particle, two of these larger particles unite to form still larger particles, and so on until the process is complete. Before the fat particles can unite, the materials adsorbed on them are brought into equilibrium in the aqueous phase—the buttermilk. The fat particles disrobed of these protective materials are now more readily amalgamated through the forces of concussion.

Another theory of churning, known as Rahn's or the foam theory of churning, holds that air is necessary. According to this theory, air is incorporated in the cream in the churning process to form foam; the fat globules then concentrate on the film of the foam to form clusters of fat particles which readily unite with other clusters, ultimately forming butter. According to the proponents of this theory, the fat globules of milk retain their identity in butter, having a thin film of water and stabilizing colloid surrounding them. While this theory is not generally accepted, it is well known that fat particles cluster on the films formed by foam to give rigidity, as in the whipping of cream. When the whipping of cream proceeds beyond a certain stage butter is formed.

Butter, however, can be churned without air or foam. The author found that no more agitation of cream was required for churning in the absence of air than when the normal amount of foam was formed.

Churning practices. The churning procedure involves all of the steps from the proper preparation of the churn to the removal and packing of the churned butter.

The churn varies from the small contrivances used on farms, that have capacities of as low as 25 pounds of cream, up to the large factory sizes having capacities of 3 or 4 thousand pounds of cream. The small churns may be of the barrel, dasher, swing, or box types, most of which are run by hand power. The factory churn consists essentially of a large horizontal barrel mounted on an axis at each end and equipped with special rolls for working the butter. A few commercial churns are not equipped with apparatus for working; when this type is used, the butter must be removed and worked in special apparatus. Most churns are constructed of wood because butter is more likely to stick to metal than to wood. There are some metal churns, however. (Fig. 135.)

Preparing the churn. The first essential is to have the churn well cleaned and well soaked (if of wood construction) before charging it with cream. The churn may be a source of bacterial and mold contamination that may cause rapid deterioration unless it is carefully cleaned and sterilized before use. The soaking is essential to prevent the sticking of the butter. The churn should also be cooled below the temperature of the cream.

Loading the churn. No more cream should be placed in the churn than will permit maximum agitation—⅓ to ½ full is usually the best load.

Butter color. The proper amount of butter color is now added. This should be carefully measured and apportioned on the basis of the amount of butterfat in the churn and the amount of color found necessary.

The churn is then run until the butter granules are the size of peas, when it is stopped and the buttermilk drained off.

Rinsing the buttermilk off the fat and inside of the churn by spraying with water of the same temperature as the buttermilk is the next step.

Washing. After the rinsing, the butter is washed by filling the churn with water of the same temperature as the buttermilk to the same mark as that reached by the cream, and revolving the churn for a few rounds.

Salting. After the wash water is drained, the desired amount of salt is added. The amount of butter is calculated from the test of the cream, and from this the amount of salt needed can be determined. To secure the proper amount of salt an excess of about 50 per cent must be added. If the butter is low in moisture content, however, less salt is added. The excess salt is added to take care of salt losses in the water forced out of the butter in working, and it consequently varies with the amount of excess water.

The butter is now worked to compress the fat granules and uniformly incorporate the water and salt. If the butter contains too much water, it may be reduced by more working. If the butter contains too little water, the necessary water is added and worked into the butter. Proper working is also important from the standpoint of the texture of the butter. When the butter is properly worked, it has a homogenous appearance, is free from visible moisture particles, and has a firm and waxy appearance. Underworked butter is usually not firm in appearance and has visible water particles. Overworked butter becomes dull in color and greasy or salvy in appearance.

Factors influencing churning. The object in churning is to obtain the best possible texture of butter with the most exhaustive removal of butter-fat from the buttermilk in the shortest period of time. The butter must be of a firm texture when churned or an inferior product will be obtained. If the butter is too soft when it is churned, the finished product will be greasy and leaky, as well as too high in serum content.

Temperature of the cream when churned is one of the most important factors in butter making. The temperature used is the one that will produce butter granules of the correct consistency for proper working. The temperature at which cream should be churned varies, depending upon the composition of the fat and the season of the year. In the winter the correct temperature is usually about 50° F., while in the summer the cream should be cooled to at least 46° F. Fats produced on grass are softer than those produced upon dry winter rations. There is also an apparent seasonal effect, not related to the feed, upon the softness of fat.

Temperature also affects the exhaustiveness of churning. Lower temperatures make necessary longer periods of time for churning and more exhaustive removal of the fat from the buttermilk. A temperature at which butter will be produced from sour cream in 45 minutes and from sweet cream in 50 to 60 minutes of churning is the most desirable. Higher churning temperatures lower the time required for butter to come but spoil the texture and cause a retention of too much of the serum. Higher temperatures also increase the losses of fat in the buttermilk.

Cream should be cooled for several hours at the temperature at which it is to be churned, or, better still, at a temperature of several degrees below

the desired churning temperature. The reason for this is that the fat cools much more slowly than the serum part of the cream. Time is required for the cooling and hardening of the fat to the proper consistency for efficient churning.

The size of the fat particles is an important factor in the rapidity of churning. Cream from breeds producing large fat particles (Jersey and Guernsey) churns more rapidly and more exhaustively than cream from the breeds producing small fat particles (Holstein and Ayrshire). The fat particles decrease in size with the advance in lactation, and, therefore, cream from cows that have been milked for a long time churns with greater difficulty than that from cows more recently fresh.

The richness of the cream is also a factor in the rapidity of churning. The higher fat content creams churn more rapidly than those with lower fat contents; this is due, no doubt, to the shorter distance between the fat particles in the rich cream. Cream with 30 to 35 per cent fat content is the best for churning.

Viscosity is directly correlated with churning. Increased viscosity lengthens the time required for churning and increases the fat losses. The lengthening of time is due to the resistance of the cream to agitation and movement of the fat particles. Increased fat losses are due to the adhering of the viscous cream to the churn, later to be released in the buttermilk.

Sour cream churns more rapidly with less loss of fat in the buttermilk than does sweet cream, largely because of the reduced viscosity. High acid reduces viscosity by changing the protective nature of the proteins of the cream. Slight acidity may increase the time required for churning, as the viscosity is increased by increased acid up to the point where the casein begins to precipitate, when there is a decrease in viscosity.

The load and the speed of the churn affect the speed of churning to the extent that agitation is affected. Overloading the churn naturally decreases the amount of agitation and lengthens the churning time. The speed of the churn, likewise, should be adjusted to give the maximum agitation. If the churn is run too fast, the centrifugal force will hold the cream against the outer walls without agitation. If the churn is turned too slowly the cream will be held practically stationary at the bottom of the churn by gravity forces.

Cream from cows in advanced lactation is difficult to churn; in some cases it will not churn at all. This is to one or both of two reasons—too small fat particles and the action of lypase, a fat-splitting enzyme. With advance in lactation there is a progressive decrease in the size of the fat particle. Increased lypase content of the milk is not constant but is frequently associated with advanced lactation. Lypase splits the fat into fatty acids and gycerol. The fatty acids unite with the cations of the milk to form soaps which in turn stabilize the emulsion when present in sufficient quantities, preventing the coalescence of the fat particles regardless of the length of churning.

Difficult churning because of these factors is usually restricted to farm butter making, where most of the cream may come from cows in advanced

stages of lactation. Mixed cream from different herds will seldom come from sufficient advanced lactation milk to be a serious factor in difficult churning.

When lypase is the cause of difficult churning it will be indicated from the development of a bitter taste in the cream. This bitter taste is not present when the milk is drawn but develops upon standing, usually requiring 12 or more hours before it becomes pronounced. This difficulty may be overcome by heating the milk or cream to at least 180° F. soon after it is produced.

Factors influencing the fat losses in buttermilk. The importance of keeping the losses of fat in buttermilk to a minimum is obvious. The factors influencing the losses of fat in the buttermilk have been indicated in the previous discussion, but because of the importance of the problem they will be recapitulated here. The chief factors are:

1. Temperature of churning and tempering of the cream before churning. The fat particles of the cream must properly congealed.
2. The acidity of the cream. Sour cream churns more exhaustively than sweet cream. Losses in sweet cream buttermilk are reduced by lowering the churning temperature and increasing the length of churning.
3. Size of the fat particles. Creams with small fat particles entail heavier losses in the buttermilk than do creams with larger fat particles.
4. Pasteurization of sour creams frequently causes a locking up of fat in the hard lumps of casein formed by this process, and an increased loss in the buttermilk.
5. Viscosity of the cream causes fat losses in the buttermilk because creams with high viscosity stick to the churn parts and are not churned.

GRADING AND SCORING BUTTER

Kinds and grades of butter. All butter may be divided into two general groups depending upon whether the cream from which it is made is raw or pasteurized. All butter may also be divided into salted or unsalted groups. In addition to these there are a number of other classifications of butter that are used in the trade. They are:

Creamery butter: The butter made in any creamery or plant where butter is churned.

Farm butter or dairy butter: Butter made on the farm where the cream is produced.

Ripened cream butter: The butter made from cream that has been ripened by the addition of a starter.

Sweet cream butter: Butter made from cream containing not more than 0.2 per cent acid at any time.

Whey butter or whey cream butter: The butter made from cream skimmed from whey. It may be either sweet or cultured.

Renovated or process butter: The butter made from refined and reworked butter of inferior quality, usually packing stock.

Packing stock: The butter unsuited for human consumption.

In addition to the above classes, butter is also sold under definite market grades based upon quality. These grades with the scores necessary follow.

Special or better than extras must score 93 or above.

Extras: Must score at least 92.
Firsts: Scores from 88 up to 92.
Seconds: Scores from 83 up to 88.
Thirds or Packing Stock: Butters unsuited for human consumption.

Scoring butter. Most butter sold on the market is scored by experts. For scoring the following score card is used:

Characteristic	Points Allowed
Flavor	45
Body	25
Color	15
Salt	10
Package	5
	100

While the points on the score card total 100, the peculiar thing about butter scoring is that it is never scored 100 even though no fault can be found. Butter on the market is seldom scored above 94. In butter contests scores as high as 96 may be allowed.

Flavor is naturally the most important consideration and, consequently, nearly one-half of the total points, outside of that for package, is reserved for this characteristic. Flavor is a difficult character to describe. It cannot be determined chemically. Since flavor is caused by compounds that react upon the olfactory nerves, in reality it is due to odor rather than to taste. The latter is that which is detected by the taste buds of the tongue, by which only four types of sensations can be perceived—bitter, sweet, salt, and sour. The desired flavor of butter is described as sweet, clean, and possessing aroma. The defects in flavor are many. The more common ones are rancid, tallowy, metallic, cheesy, cooked, unclean, and a number of feed and weed flavors, as well as some flavors the characteristics of which are hard to describe.

Body. By body is meant the physical appearance of the butter. The body of good butter should be firm, of a waxy appearance, close textured and homogenous or uniform. The common body defects are: a salvy or greasy texture due to overworking; a weak texture that causes the butter not to stand up at normal temperatures; a body from which water leaks out; a sticky body, causing the butter to stick when it is being spread; and a crumbly texture, causing the butter to crumble when it is being spread.

Color. The market demands in color vary somewhat. The right color of butter is that which meets the market demands and is uniformly distributed. The present market demand is for a light straw color of butter. In the spring of the year when the cows are on pasture, particularly where Jersey and Guernsey breeds predominate, butter is too high in color. In the winter butter may be too low in color unless the proper color is

added. The color defect where yellow streaks are alternated with lighter ones—the "mottled" condition—must be avoided. This is due to the improper distribution of water and salt, and sometimes may be due to curd particles.

Salt. The amount of salt in butter varies from nothing up to 5 or more per cent, depending upon the consumer demand. The defect from improper salting is the production of a mottled condition; or so much salt may be added that salt grains are perceptible, producing a "gritty" condition.

Package. The package must be appropriate, properly lined with paper, and clean.

CREAM FOR BUTTER MAKING

Types of cream. Cream used for butter making may come from the farm where it was separated, from whole milk creameries or other processing plants such as market milk or condensed milk plants, or from cream separated from whey and known as whey cream. Naturally the cream used for butter making varies greatly in quality. The cream produced from the separation of the whole milk in plants is usually of high quality, as is much of the cream produced on the farm. On many farms, however, only such small amounts of cream are produced daily that the expense of proper cooling or frequent delivery, so necessary for quality, is not warranted. These creams are sometimes of very inferior quality.

Cream grading. Grading cream on a basis of quality has not met with great success, for two reasons. First, the competition for the producers' cream is so great that buyers are reluctant to place the proper grade on poor creams; and second, it is difficult to grade cream properly. Laws passed in Minnesota and Manitoba, Canada, have to a certain extent overcome the former of these reasons in that they make the grading of cream mandatory, but there still remains the difficulty of making the correct grades, although some progress is being made. The ideal cream for butter making is sweet (containing less than 0.2 per cent acid), clean of flavor, and free from sediment. Such cream would grade No. 1. The next best cream for butter making is that which has developed some acid but is clean of flavor and free from sediment. Such cream would grade No. 2, and for the making of ripened cream butter is very satisfactory. Lower grades of cream possess varying degrees of off flavors due to one or more of a number of causes.

Sweet cream, properly handled, may be almost unsuited for butter making because of decided weed or other feed flavors. A tallowy flavor may be very pronounced in a sweet cream due to a peculiarity of the cow or cows from which it is produced, or due to contact with some metal which catalyzes oxidation. Sweet creams, too, may possess odors that have been absorbed from exposure in rooms laden with undesirable odors.

Sour creams often develop a host of defects from the organisms they contain. In addition to extreme acidity, moldy, rancid, tallowy, musty, and decomposed flavors are frequently developed. The flavors produced

by micoorganisms are usually difficult to get rid of, as contrasted to absorbed flavors which frequently may be driven off by aeration or pasteurization.

Processing cream for churning. There are four processes to which cream may be submitted, with which students of dairying should be acquainted. These are pasteurization, neutralization, ripening, and treatment to free from odors and flavors.

Pasteurization. Since the principles of pasteurization have been treated previously, there is no need of discussing the details at this point. Most of the cream used for churning in plants is pasteurized. Either the holding or flash systems or a combination of the two may be used. Cream is usually subjected to somewhat higher pasteurization temperatures than milk—rarely lower than 145° F. for 30 minutes by the holding process.

Before sour cream is pasteurized it should be neutralized to avoid curdling. When the cream has curdled, some of the curd particles are incorporated in the butter. Other curd particles enclose fat particles and cause high fat losses in the buttermilk.

Neutralization. Before sour cream can be pasteurized, the acid must be neutralized by some neutralizing agent. For this purpose one of the following alkalies may be used: calcium oxide, calcium hydroxide, calcium carbonate, magnesium carbonate, or sodium bicarbonate, or mixtures of these compounds. In neutralizing cream care must be taken not to add too much neutralizer, as an excess may cause saponification. Neutralization should not be carried farther than back to a titration of .2 per cent acidity in terms of lactic acid.

Creams that have developed too much acid for churning should also be neutralized.

Ripening. Ripening of cream refers to the process of lactic acid fermentation started by the addition of lactic acid cultures. Most creamery butter is made from ripened cream. Sour cream is usually neutralized, then pasteurized and ripened.

Ripening is carried out by cooling the cream following pasteurization from 70 to 72° F., when 5 to 10 per cent of its weight of "starter" is added. The cream is then held at 70 to 72° F. until an acidity of 0.3 to 0.4 per cent is formed, when it is cooled preparatory to churning.

The starters consist of two types of organisms developed in milk. One type of organisms breaks the lactose down into lactic acid, and the other acts upon other compounds of the cream to form a series of volatile compounds, of which diacetyl is an example. These compounds give to the cream and butter some of the desirable flavors and aromas.

Natural souring of clean cream produces much the same effect as the use of starter. Unless the cream is pasteurized, however, the many other types of organisms present grow about equally well with the desirable types.

Removing objectionable flavors and odors. While many of the objectionable flavors and odors of cream cannot be removed by any method now known, there are several flavors that may be removed partially or entirely. It will

be possible only to list here the different methods employed for this purpose. They are as follows:

1. Blowing a current of air over a thin film of cream as it is run over a surface cooler. The cream should preferably be hot.
2. Subjecting hot cream 160° F. or above to reduced pressure, as in a vacuum pan.
3. Bubbling air through hot cream either at normal or reduced pressures.
4. Using carbon dioxide instead of air.
5. Treating the cream with chemicals that will oxidize or reduce the flavor producing compound, or perhaps in some cases counteract the flavor.

TEST USED IN BUTTER MAKING

In addition to the tests for cream and buttermilk which have been discussed previously, there are a number of other tests used in the making of butter—those for the moisture, fat, curd, and salt content, and for adulteration, foreign matter, and bacteria.

The Kohman method. This method of butter analysis has been found to be a satisfactory test for moisture, fat, salt, and curd. It has been modified by several workers to simplify the procedure.

Moisture. Weigh accurately 10 grams of butter into an aluminum dish. Drive off the moisture slowly over an open flame. When the foaming ceases all moisture has been driven off. At this point, provided the flame has been low, the curd is a light brown in color. Cool the dish and its contents to the room temperature, and weigh. Determine the loss in weight of the sample. Divide this by the weight of the butter and multiply by 100 to secure the percentage of water.

Fat is determined by dissolving the residue from the moisture determination in 100 cc. of gasoline. Thoroughly stir the mixture with a glass rod, and then allow it to settle for at least five minutes. Carefully decant off the gasoline solution into a separate container. Repeat the process with another 100 cc. of gasoline. Drive off the remaining gasoline over the same heat used for the moisture determination. Weigh and determine the net loss in weight of the sample. Divide this by the weight of butter used and multiply by 100 to secure the fat percentage.

Salt is determined from the residue by the following method: Add 100 cc. of distilled water to the residue, and stir thoroughly with a glass rod. Pipette 10 cc. of the mixture into a flask or white cup for titration with a silver nitrate solution. First add two to three drops of 10 per cent potassium chromate solution. Then titrate the silver nitrate solution (29.062 grams with enough water to make a liter) into the solution until a brownish color appears. The number of cc. of silver nitrate solution used equals the per cent of salt in the butter.

Curd. The sum of the percentages of moisture, fat, and salt subtracted from 100 gives the percentage of curd. In the curd as here used are also the lactose and ash, as well as the proteins.

Other methods. The fat may also be determined by the Babcock method in special butter test bottles and by the Majonnier method, which is the most accurate, but which requires especially constructed equipment. Moisture may also be determined accurately by the Majonnier method.

The microscope is used to determine and identify foreign material. Filter pads are also used.

Bacterial mold and yeast content are determined by standard bacteriological methods.

To assist in determining whether butter has been adulterated the various fat constants are determined.

BY-PRODUCTS OF THE BUTTER INDUSTRY

Where butter is made, two by-products result directly—skim milk and buttermilk. In most cases both of these are fed to livestock on the farm, but an increasing proportion of both of these products is now used for the manufacture of powdered skim milk and buttermilk, casein, condensed milk, and buttermilk for semisolid buttermilk.

Chapter 52

CHEESE

CHEESE MAKING, AS WELL AS BUTTER MAKING, IS ONE OF THE EARLIEST ARTS connected with dairying. The time when cheese was first made antedates the earliest of human records. The first cheese made was probably the result of natural souring; this was followed by cheese made from rennin, coagulation of milk, and ripening. While cheese making is still an art, science plays an important part in the making and curing of cheese. Modern cheese making draws upon chemistry and bacteriology for the control of the entire process, beginning with the milk and including all the steps in the making and curing of cheese.

Cheese differs markedly from butter in its composition, structure, and the chemical parts of the milk that are used. The processes involved in the manufacture of cheese are unlike those involved in butter making, and the processes for the manufacture of the different cheeses also vary greatly.

Types of cheese. The several hundred varieties of cheese may be divided into different classes or groups. There are different bases used for such a classification. One uses the hardness of the finished cheeses as a basis for division, while another uses the condition or character of the milk or product from which the cheese is made as a basis for classification.

On the basis of the hardness the cheeses fall into the following groups, with the subdivisions based upon the methods used in making and the organisms employed:

- I. Soft cheese
  - 1. Unripened—cottage and cream cheeses
  - 2. Ripened by bacteria—Limburger
  - 3. Ripened by molds—Camembert
- II. Semihard cheese
  - 1. Ripened by bacteria—brick
  - 2. Ripened by molds—Roquefort
  - 3. Made from whey—primost
- III. Hard cheese
  - 1. Without gas holes—Cheddar
  - 2. With gas holes—Emmenthal or Swiss
- IV. Processed or reworked

On the basis of the product used, cheese may be classified into the following groups:

- I. Rennet or sweet milk cheese
  - 1. Soft cheese
    - a. Ripened by bacteria
    - b. Ripened by molds

2. Hard cheese
   a. With gas holes
   b. Without gas holes

II. Sour milk cheese

III. Whey cheese

IV. Process cheese

In the United States the principle cheeses made are those of the hard variety—Cheddar and Swiss cheese. Among the soft cheeses the unripened varieties, cottage cheese and cream cheese, constitute the principle ones. The manufacture of the other types of cheese is not extensive, although practically all types are now manufactured in this country. (Fig. 136.)

THE PRINCIPLES OF CHEESE MAKING

While the methods employed in the making of different cheeses vary widely, there are two sets of processes involved. The first is the production of the coagulum, and the other is the curing or ripening processes.

The coagulum. With the exception of whey cheese, casein forms the common and basic constituent of all cheeses. The other milk constituents present in cheese are either dispersed in the water present or are locked up in the coagulated casein. The casein may be coagulated by one or a combination of the following three methods: acid; rennin; pepsin.

In the case of the whey cheeses, all the whey constituents are condensed by the evaporation of the water.

Acid coagulation is used for the production of acid cheeses, such as cottage cheese and cream cheese. The acid is usually developed by the addition of a starter to the milk or cream from which the cheese is to be made, and incubated until sufficient lactic acid has developed to precipitate out the casein. The principle of acid precipitation of casein has been discussed previously. In brief it consists of a removal of the calcium from the calcium caseinate to form casein and calcium lactate. The casein is not stable and comes out in the form of large coagulums known as curd.

Rennin and pepsin coagulation. Rennin and pepsin must be considered together, as the commercial rennet also contains pepsin. Both of these enzymes possess the power of coagulating milk. Rennin, used for cheese making, is secured principally from the stomachs of suckling calves. An extract of the lining of the fourth stomach (abomasum) constitutes commercial rennins, known as rennet.

Although both rennin and pepsin will coagulate milk, rennin is believed to possess only the ability of coagulation, while pepsin will, in addition, break the casein down into simpler compounds known as peptides.

Rennin coagulation differs markedly from acid coagulation. The exact nature of rennin coagulation is, as yet, not universally agreed upon; but the majority believe that a calcium paracaseinate is formed. It is thought by many that the calcium paracaseinate is formed by breaking the casein molecule into simpler molecules with the addition of calcium. The rennin coagulum, therefore, contains more calcium than the calcium caseinate of the milk, while the acid coagulum contains less calcium. Sometimes milk

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Fig. 136. Some of the many different forms and packages in which cheese is sold.

contains too little calcium for the coagulation by rennin. When this is the case, the difficulty may be overcome by the addition of a calcium salt, such as calcium chloride. After the rennin has acted upon the milk, the whole sets into a gel. The gel, at proper temperatures, contracts to squeeze out the water, containing materials in solution and dispersed therein; this is commonly called whey.

Curing processes. With the exception of some soft acid cheeses that are ready for consumption when they are made, all cheeses go through a storage period in which marked changes take place. The changes that take place during the curing process are not fully understood, but they consist largely of a breakdown of the various constituents of the cheese. The lactose may be broken down into lactic acid and other compounds, the paracaseinate and other proteins are broken down into simpler protein constituents and in some cases down into amino acids, and the fats may be broken down into fatty acids.

The breakdown of the different constituents is caused by the different organisms present in the milk or added to the milk for cheese making, as well as the action of added enzymes. As different organisms cause different breakdown products, specific organisms are added for the production of specific cheeses. A special mold, *Penicillium roqueforti*, is used for the production of Roquefort cheese, and *Penicillium camemberti* is used for the production of Camembert cheese. In other cases the curing conditions are so controlled as to favor the development of certain organisms present in the milk in order to secure the type of reaction desired. This is accomplished to a great extent by adjusting of the temperature and moisture conditions during the curing period.

The chemical composition of cheese. The composition of cheeses varies widely within the different varieties as well as between them. The variations may be observed in the following table. Water and fat are the

NORMAL VARIATIONS IN COMPOSITION OF CHEESE, AND YIELDS PER 100 POUNDS OF MILK

	Water	Protein	Fat	Ash	Yield per 100 Pounds of Milk
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Pounds*
Brick	37 to 40	22 to 24	27 to 33	4.0 to 4.5	11 to 13
Camembert	47 to 50	18 to 21	25 to 28	2.0 to 3.0	12 to 14
Cheddar	34 to 42	21 to 25	30 to 36	3.5 to 7.0	9 to 13.5
Cottage	70 to 75	13 to 20	Trace to 2%	2.0 to 3.0	14 to 19
Cream	38 to 43	13 to 16	43 to 48	0.5 to 1.5	15 to 20 per 100 cream
Limburger	39 to 43	21 to 25	26 to 30		12 to 14
Neufchâtel	50 to 55	18 to 21	23 to 28	0.5 to 1.3	12 to 14
Roquefort	37 to 40	19 to 23	31 to 34	5.0 to 7.0	
Swiss	30 to 34	25 to 30	30 to 34	3.0 to 5.0	8 to 11
Primost	10 to 20	10 to 15	1 to 2	30 to 55 milk sugar	

most variable constituents. The soft cheeses are higher in water content than the hard cheeses. Cottage cheese is the lowest in fat content, and cream cheese is the highest in this respect. The protein content varies within much narrower limits, with the exception of primost, which is low in its protein content.

Products from which cheese is made. Cheese may be made from whole milk, skim milk, cream, or whey. Of these, whole milk is by far the more important, as Cheddar cheese, Swiss, Limburger, Roquefort, etc. are all made from whole milk. Skim milk, used principally for the making of cottage cheese, is also used for the making of certain "skim milk" Cheddar cheeses. Cream is used for the production of "cream" cheeses. Whey is used for the production of primost.

Cow's milk is the product most extensively used for cheese making; next is goat and sheep milk, which are used extensively in Europe for the production of certain types of cheese. Roquefort cheese is made from sheep's milk. Mare's milk is also used for cheese making.

Quality of milk. Cheese making requires milk of high quality from the standpoint of flavor and its microorganism content. The flavors of milk are carried over into the cheese. Bad feed flavors of the milk may practically ruin cheese. Undesirable microorganisms in the milk, including bacteria, yeasts, and molds, will produce undesirable effects upon the cheese during ripening.

The amount of fat in the milk affects both the yield of cheese and the fat content of the cheese. With increased fat content of the milk there is an increase in both the yield and per cent of fat in the cheese. This is accounted for by the fact that with increased fat content of milk there is an increase in casein, but the increase in casein is not proportionate to the

increase in fat. The following table shows the increase in yields of cheese and pounds of cheese per pound of fat for milks of different fat percentages:

Per Cent Fat in Milk	Yield of Cheese	Pounds per Pound of Fat
Per Cent	*Pounds*	
3.4	9.0	2.73
3.7	10.0	2.73
4.2	11.4	2.70
4.7	12.8	2.70
5.1	13.6	2.66

MANUFACTURE OF CHEESE

The manufacturing processes employed in the production of different cheeses vary greatly. It will be possible here to treat the manufacture of only a few of the more common cheeses, and then only in outline form. Of the hard varieties, the most common cheese in the United States is the American Cheddar cheese; this is followed in importance by the Swiss cheese. In the semihard group, brick cheese leads, with small amounts of Camembert and Roquefort also made. For the soft cheeses cottage cheese, cream cheese, and Limburger are of major importance. The steps in the manufacture of Cheddar cheese will be considered, followed by a consideration of the most important features in the production of the other cheese mentioned.

Hard Cheeses

Cheddar cheese. Following is a consideration of each of the important steps in the manufacture of Cheddar cheese:

Milk. Fresh, clean milk is placed in a suitable vat known as a cheese vat. This vat has an outer jacket for heating purposes. Water in this jacket may be heated by steam.

Ripening the milk. An acidity of about 0.2 per cent in terms of lactic acid is the best for cheese making. Fresh milk may be brought up to this acidity by holding for the proper length of time or by adding enough starter to bring the acidity immediately.

Heating the milk. After the milk has been properly ripened, it should be heated to between 86 and 88° F. Lower temperatures produce too soft curd, and higher temperatures produce a curd that is too tough.

Adding color. The proper amount of cheese color should then be added and thoroughly mixed by stirring.

Rennet is now added in sufficient quantities to completely set the milk within 25 to 35 minutes. Under ordinary conditions from 2.5 to 4 ounces of commercial rennet are added per 1,000 pounds of milk. The rennet extract should be diluted in 40 to 50 parts of water and thoroughly stirred into the milk.

Setting. The milk is permitted to set while the rennet coagulates it. In order to determine when the curd is firm enough for cutting, it is pushed away from the walls of the vat or broken by inserting the forefinger obliquely into the curd and raising. If the curd breaks away cleanly from the vat in the former or breaks sharply in the latter it is firm enough for cutting.

Cutting the curd. When the curd is of the proper firmness it is cut into ½ to ¾ inch cubes to facilitate expulsion of water. The cutting is done by two curd knives with a number of parallel blades or wires running vertically in one knife and horizontally in the other. The horizontal knife is passed lengthwise with the vat and the vertical knife is passed both lengthwise and crosswise.

Heating. Following cutting, the curd is toughened by heating, which is usually referred to as "cooking." The whey and curd are slowly heated to 100 to 103° F. About 35 minutes should be required to accomplish this.

Stirring. While the vat is being heated the curd must be stirred or it will settle to the bottom of the whey and "mat." Stirring is effected by agitation with cheese rakes which are pulled back and forth in the vat, or by a mechanically operated stirring apparatus.

Draining the whey. When the curd particles have shrunk to half or less of the original size and have assumed a tough, rubbery characteristic, the whey is drained off.

Cheddaring. The process from which this type of cheese derives its name is known as cheddaring. It consists of piling the curd, either in a vat or in a special curd sink, in a layer 4 to 5 inches in depth. Here the curd particles adhere to form a solid mass. This is also known as matting. Whey is being forced out from the curds during this process. The mass is now cut into strips 8 to 12 inches in width and up to twice this in length and are piled 5 to 6 slabs deep.

Milling the curd. After cheddaring is completed, the slabs of curd are passed through a curd mill; this is a machine, usually operated by hand, for cutting the curd into small pieces. The pieces are usually strips about 1 by 1 by 2 inches. The milling is done to facilitate salting, packing in the hoops, and further drainage of whey.

Salting. Salt is added to the milled curd at the rate of 1½ to 2½ pounds per 1,000 pounds of milk used. The curd is thoroughly stirred to facilitate distribution of the salt.

Packing in hoops. The cheese hoop is a heavy steel cylinder of the diameter desired for the cheese. The hoop is lined with cheesecloth and the milled curd is packed therein. When filled the hoop is put into a cheese press, where pressure is applied to squeeze the curd particles into one homogenous mass. The cheese is usually left in the press for a period of 48 to 72 hours.

Hoops used. Cheddar cheese is invariably packed in hoops, but the diameter of the hoops varies according to the size of cheese to be produced. There are seven different sizes, and cheeses of each size or shape have a

special name. Export weighs 75 to 90 pounds; Cheddar, 40 to 50 pounds; Flats, 35 to 40 pounds; Twins or two in a box, 35 to 40 pounds each; Daisy, 20 to 24 pounds; Young America, 10 pounds; and Longhorn, 10 to 15 pounds. With the exception of Longhorn, which tapers, all these cheeses are flat and circular.

Drying. After the cheese is removed from the press it is placed in a cool, dry place for 3 to 5 days to permit the outer surface to become thoroughly dry.

Paraffining. When thoroughly dry, the cheese is coated with paraffin by dipping it into a vat of paraffin heated to 215 to 230° F.

Curing. The paraffined cheese is now placed in the curing rooms at from 45 to 60° F. Cheddar cheese may be held in the curing rooms for a year or more, but it is usually removed in 3 months. Longer curing produces a more desirable cheese, but it adds to the expense of production. The breakdown of lactose is continued in the early curing stages by *S. lactis*. *Lactobacillus casei* is chiefly responsible for the protein breakdown.

Skim milk Cheddar cheese. Skimmed or partly skimmed milk may be used in making Cheddar cheese. The processes are identical to those just described. Cheese made from skimmed or partly skimmed milk must be so labeled when offered for sale.

Swiss cheese. Swiss cheese is variously known as Emmenthal, Gruyère, or Schweitzer. It was developed in Switzerland, and ranks next to Cheddar cheese in this country in the amounts made. It is characterized by holes ½ inch to 1 inch in diameter and 1 to 3 inches apart.

The manufacture of Swiss cheese differs from that of Cheddar cheese in that it is made in circular kettles instead of vats; the curd is not cheddared, but lifted out in a press cloth; and the curds are cooked at a higher temperature, 125 to 128° F. It differs also in the methods of salting and of curing.

Circular kettles are used to facilitate the removal of the curd, which is done by slipping a cloth under the curds in the whey and hoisting the mass out with the aid of a block and tackle. The curds are cooked at a higher temperature to express the whey, which the cheddaring process accomplishes for Cheddar cheese.

Starter made with a pure culture of *Lactobacillus bulgaricus* is often used to produce lactic acid, which in turn suppresses other undesirable fermentations. *Streptococcus thermophilus* plays an important part as it survives the high temperatures to which the acid is subject and develops rapidly at these temperatures. Then cultures made from cheeses with desirable eyes are added, or pure culture of the two organisms which are responsible for the eye formation—*Lactobacillus casei* and *Propionibacterium shermanii*—may be used.

The curd is pressed in the same manner as the Cheddar cheese curd is. Salting is accomplished either by leaving the cheese in a strong brine solution for several days or by rubbing the cheese with dry salt.

The curing requires two processes—one to develop eyes, and the other to continue the ripening process. A temperature of 70° F. is maintained

in the curing room for the development of eyes; this process usually requires about two weeks. The remainder of the curing process is carried on at 60° F. From 3 to 10 months are required for the curing process.

Semihard Cheeses

Brick cheese. Brick cheese is made from low acid milk—not over 0.16 per cent lactic acid equivalent. It, therefore, requires fresh milk to which a small amount of starter is added. The milk is curdled by rennet and cut in the same way as Cheddar cheese is. It is "cooked," however, at a higher temperature—110 to 115° F. During the "cooking" process the curd is constantly stirred.

The whey is not drained off the curds as for Cheddar cheese, but the curds are dipped out of the whey. They are then packed into forms 10 inches long by 8 inches deep, and are pressed by the application of weights, such as bricks.

The cheese is salted by rubbing or by soaking in a brine solution, and is then placed in curing cellars at 60 to 70° F., with high humidity. From 4 to 6 weeks are required for the curing process.

Roquefort types. True Roquefort cheese is made in Roquefort, France, from sheep's milk. In America Roquefort-like cheeses have been made for some time from cow's milk. Roquefort cheese is characterized by the following:

1. A firm but crumbly texture.
2. A white color except for the blue spots caused by blue molds.
3. A strong, peppery flavor due to the presence of a number of the lower fatty acids of butterfat—caproic, capric, and caprylic acids. These are products produced by the action of the mold upon the butterfat.

Roquefort cheese is made from milk by bringing the acidity up to 0.20 per cent with a starter. It is then coagulated by rennet at 85° F. The curd is not "cooked," but is removed from the whey 20 minutes after it is cut. It is drained for about 20 minutes, and then it is packed in the proper forms (circular hoops 6 inches high and 7⅜ inches in diameter). Spores of the mold *Penicillium roqueforti* are sprinkled on the curds as they are packed.

After 24 hours the cheese is removed from the molds and salted by rubbing from 6 to 8 pounds of salt on each 100 pounds of cheese. After salting, the cheese is pierced by long needles to admit air and allow the mold to grow. In the finished cheese the blue mold spots follow the needle punctures.

The cheese is cured in cellars at about 50° F. and 90 to 95 per cent relative humidity. In France the natural caves near Roquefort furnish these conditions; in America they are usually created by artificial means. From 5 to 8 months are required for the curing process.

Gorgonzola, originating in Italy; Stilton, developed in England; and Port du Salut of France are types of foreign cheese belonging to the semi-

hard class which are made to a certain extent in various parts of this country.

Soft Cheeses

The soft cheeses may be divided into two groups—those that are not ripened and those that are ripened. Among those that are not ripened are cottage cheese, Neufchâtel, and cream cheese; these are important among American cheeses. In the ripened group of soft cheeses are Limburger and Camembert.

Unripened Soft Cheeses

The unripened soft cheeses are either coagulated by acid alone, or acid formation plays an important part in their production. Cottage cheeses and cream cheese are produced by curdling the milk or cream with lactic acid formed by souring. Neufchâtel, in addition to souring, is produced by the addition of some rennet.

Cottage cheese. Cottage cheese is usually made from skim milk, although whole milk is sometimes used. On the farm it is usually produced from naturally soured milk, while in the factory it is produced from pasteurized milk held at about 70° F. after pure culture starter has been added. In about 10 to 15 hours sufficient acid has formed to completely curdle the milk. The curd is either cut or broken up and heated from 100 to 110° F., when the whey is drained off. The curd is then drained by suspending it in cheesecloth. After it is drained the curd is salted and usually cream is thoroughly worked in to improve both the flavor and the texture. From 1 to 2 per cent of salt and 3 to 5 per cent of 30 per cent cream are customarily used.

Cream cheese. Cream cheese is made from cream of varying fat contents. The cream is usually homogenized and pasteurized before being soured by the addition of starter. Rennet is also added to assist in the coagulation. To lower the whey content of cream cheese it is necessary to drain the coagulated cream in suspended cheesecloth bags. This usually requires several days and must be done in a cold room to avoid the development of undesirable organisms.

Neufchâtel cheese. Neufchâtel cheese is made from skim milk, whole milk, or cream by the same methods used for the making of cream cheese. The curd is not heated, but is drained in racks lined with cheesecloth. Neufchâtel cheese is usually packed in small cylinders that will contain 2 to 5 ounces of cheese.

Ripened Soft Cheeses

As has been previously noted, Camembert and Limburger are the two principal ripened soft cheeses produced in America. Camembert is ripened by molds, while Limburger is ripened by the action of bacteria.

Camembert cheese. Camembert cheese was first made in the community of Camembert in northern France, from which it is still imported.

It is a small disclike cheese about 1 inch thick and 5 inches in diameter, with a hard, thin rind and a soft, creamy interior.

The milk is coagulated by rennet at about 85° F. The curd is not cooked but is dipped into forms, and pure cultures of *Penicillium camemberti* are added.

The most important factor in the production of Camembert cheese is curing under the proper conditions. A temperature of 52 to 58° F. and high humidity are required for 15 to 20 days. At this time the interior of the cheese begins to soften. The ripening process is continued for 5 to 8 weeks at a lower temperature.

Limburger cheese. Limburger cheese derives its name from the town of Limburg, Belgium, where it was first made. This cheese is usually marketed in bricks of about 2 pounds in weight. It possesses a strong odor and taste.

Limburger is made from unpasteurized milk coagulated by rennet at 90 to 96° F. No starter is used. Without further heating the curd is dipped into the molds and drained for 24 hours. When it is drained, the cheese is salted by rubbing it with dry salt.

After it is salted the cheese is placed in the ripening cellar at 60 to 64° F. in a moist atmosphere. Curing is effected by the bacteria present in the milk which break down the casein under the proper curing conditions. From 2 to 3 months are required to cure Limburger.

Liederkranz and Münster cheese resemble Limburger.

Primost. Primost or whey cheese is made by evaporating the water out of the whey by heat until it is of a doughy consistency. This is then packed in the form of bricks. This product consists mainly of milk sugar but contains also the milk albumin and all the water soluble materials of milk.

BY-PRODUCTS FROM CHEESE MAKING

Whey is the only direct by-product from the making of cheese. From 80 to 90 pounds of whey are produced per hundred pounds of milk used for cheese making. Whey from rennet coagulated milk averages from 6.5 to 7.5 per cent of dry matter, 4.5 to 5.2 per cent of lactose, 0.8 to 0.9 per cent of protein, 0.3 to 0.5 per cent of fat, and 0.6 to 0.7 per cent of ash. It also contains all of the riboflavin of the milk.

Whey is still used mostly for livestock feeding and the production of primost, both of which have been noted previously. Whey is also used for the production of whey powder, condensed whey, milk sugar, and riboflavin or vitamin G. In most cheese plants the whey is separated for the fat. The cream so produced is known as whey cream.

Whey powder is used in candy making and in various baked and other products. Condensed whey is used for similar purposes. Milk sugar is used extensively as a food and for medical preparations. Riboflavin is now available as such, prepared from whey. A more extended use of whey powder can be looked for.

Chapter 53

CONDENSED AND DRIED MILK

THE CONDENSING AND DRYING OF MILK SERVE TWO MAIN PURPOSES—reducing the bulk and improving the keeping quality. For many uses, such as baking, ice cream making, and candy making, a more concentrated product than fluid milk is highly desirable. In these products the use of concentrated milks permits the utilization of much larger quantities of milk solids than would be possible if fluid milk were used. While dried milks and condensed milks are subject to deterioration with age, they are much less perishable than fluid milk.

The use of concentrated milks has been increasing considerably, and indications are that further extension of this branch of the industry may be expected. The modern methods of manufacture of these products apparently preserve all the food values of the milk that are present in pasteurized milk, but the flavor of the finished product and of the reconstituted products are different from that of fluid milk. This altered flavor is one of the large problems in the industry and the one obstacle to a more generalized use of condensed and dried milks.

CONDENSED MILK

Definition. Condensed milk is the term applied to milk, either whole or skimmed, that has had a portion of its water removed. Condensed milk may be sweetened or unsweetened, or it may be made from skim milk or whole milk.

When condensed milk is not sweetened and put up in hermetically sealed cans, it is usually referred to as *evaporated milk*. It may be either evaporated whole milk or evaporated skim milk.

When condensed unsweetened milk is sold in bulk it is usually referred to as *plain condensed skim milk* or *plain condensed whole milk*.

Superheated condensed milk is unsweetened condensed whole or skim milk that has been heated to a temperature of 185 to 195° F. after condensing. As a result it has a more viscous body; this is desirable for many products in which condensed milk is used.

Either condensed skim milk or whole milk may be sweetened by the addition of 40 per cent of sucrose. Such milks are known as *sweetened condensed skim milk* or *sweetened condensed whole milk*.

Semisolid buttermilk is sour buttermilk condensed to a product of semisolid consistency. The buttermilk to be condensed usually contains over 1 per cent lactic acid, and the finished product contains as high as 6 per cent acid.

Composition. The minimum fat and total solids content of condensed milks is fixed by federal and several state laws. The federal standard

sets the minimum for evaporated whole milk to be 7.8 per cent fat and 25.5 per cent total solids. For sweetened condensed whole milk the minimum requirements under the Federal standards are not less than 8 per cent fat and 28 per cent milk solids. Sweetened condensed skim milk must contain at least 24 per cent and evaporated skim milk 20 per cent of milk solids.

As condensed and evaporated milks are sold under highly competitive conditions, they are usually standardized to the minimum that is required by law. The amounts of the various ingredients vary according to the composition of the milk received. The average composition of condensed and evaporated milks meets the minimum requirements as follows:

	Water	Fat	Protein	Lactose	Ash	Added Sugar
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
Evaporated whole.......	74.5	7.8	6.5	9.5	1.5	0
Evaporated skim........	80.0	.1	7.3	11.0	1.6	0
Condensed whole........	32.0	8.0	7.35	11.05	1.6	40.0
Condensed skim.........	36.0	.1	8.7	13.3	1.9	40.0

These values are calculated on the basis of milk serum of average composition, assuming that the minimum requirements for both fat and total milk solids are just met.

The sugar used in sweetened condensed milk may be either sucrose or part glucose and sucrose. Other constituents in condensed milk are present in the proportion that the milk is condensed. The carotene, lactoflavin, and vitamins B and D are increased in condensed milk to the same extent that proteins, fat, lactose, and ash are. The enzymes are either destroyed or inactivated.

Plain condensed milk is frequently condensed to varying degrees to meet special trade demands. Sometimes it is condensed 3½ to 4½ :1.

Properties of condensed milks. In addition to its greater concentration, condensed milk differs from milk in its physical properties and in taste and flavor. All condensed or evaporated milks are much more viscous. The sweetened condensed milks are even more viscous because of the additional sugar content. The superheated condensed milk is still more viscous because of the heat coagulation of the proteins.

The fat does not rise in evaporated whole milks because of homogenization, which divides the fat into particles that are too fine to rise. The high viscosity also helps in preventing the fat from rising. Tinned evaporated milks are shaken vigorously after the heat sterilization to break up the protein structure, which would otherwise set into a thick gel structure.

The flavor of condensed milk is different from that of the natural milk from which it is made. This, like all flavors, is difficult to describe; in the freshly prepared product it approaches a slightly scorched or cooked flavor and varies to a decided "condensed milk" flavor in the aged

product. Loss of certain volatile flavoring constituents in the condensing process, effects of the prolonged heating, and concentration of the various milk constituents are causes for the altered flavors in the fresh product. The development of strong flavors with aging is due to chemical changes that take place.

Keeping qualities. While one of the chief advantages of condensed and evaporated milks over fluid milk is the better keeping qualities of the former, condensed milks do not keep indefinitely without deterioration. Properly canned and sterilized condensed and evaporated milks keep indefinitely without any bacterial decomposition, but chemical changes take place. There is a development of metallic flavors, increase in acidity, darkening in color, and a loss in viscosity. The higher the temperature in which canned milk is held the more rapidly these changes take place.

Unsweetened bulk condensed milks are subject to the same types of decomposition that normal fluid milks are. These milks must be kept at low temperatures to prevent spoilage.

Sweetened condensed milks in bulk keep fairly well, due to the preserving properties of the sugar. However, molds and yeasts and bacteria will develop to some extent when they are kept at higher temperatures, causing deterioration.

Condensed buttermilk or sour milk keeps well because of its high acid content.

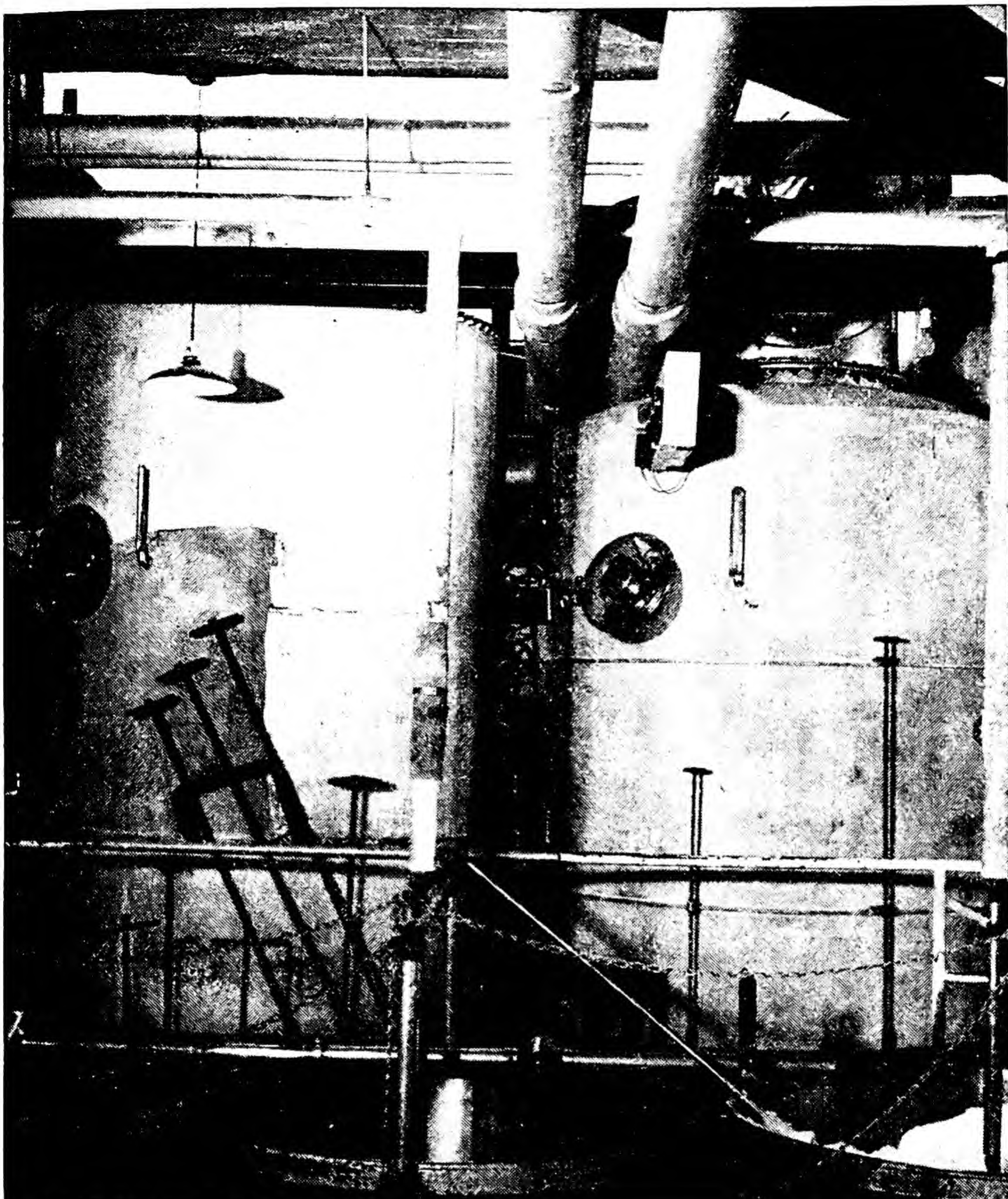
Principle of condensing. Condensing milk consists of driving off a portion of the water it contains. This is effected by the interaction of two forces—increased temperature and reduced pressure, commonly referred to as vacuum. Milk boils at 212.3° F. (100.16° C.) at sea level, while water boils at 212° F. (100° C.). As the pressure is reduced or the vacuum increased, the point at which a liquid boils is reduced. With a vacuum equivalent to 24 inches of mercury, milk will boil at about 140° F. This is found to be the most practical for condensing milk.[1]

Evaporating water with the aid of vacuum is not more economical than by the use of heat alone. Slightly more energy is expended in producing the vacuum than is saved in heat by the lowered boiling point. Vacuum is used in condensing only because the higher temperatures required for boiling at higher pressures injure the milk.

Process of condensing. To secure the proper temperatures and reduced pressure conditions of optimum condensing, careful control of the proper equipment is required.

Equipment. While the details of the equipment used for condensing vary, the most commonly used is a vacuum pan constructed of copper or some other suitable metal. This consists of a cylinder 4 to 8 feet in diameter and sometimes more than 20 feet in height. The lower part of the cylinder is jacketed and furnished with coils on the inside; both are used for heating by steam. A condenser is located in the top part of the cylinder; this is

[1] At sea level the air pressure supports a column of mercury 29.92 inches in height. A vacuum of 24 inches in mercury means that there is still sufficient air present to support 5.92 inches of mercury.



Twin City Milk Producers Association

Fig. 137. A group of two condensing pans and hot wells.

known as the dome. It consists of a trough into which cold water is sprayed and in which the vapors from the boiling milk are condensed and drained out of the pan.

The vacuum is furnished by an appropriate vacuum pump.

At the base a tank with provisions for heating the milk is connected to the vacuum pan by pipe. This is known as the "hot well." (Fig. 137.)

Method. The milk is run into the "hot well" where it is heated, usually to about 160° F.; however, this temperature varies greatly. The hot milk is drawn into the vacuum pan by the vacuum. When the coils are covered

with milk, the steam is turned on, as is the cold water in the condenser. The milk is vigorously agitated by the formation of the vapor from the heated coils and walls of the pan.

Small samples are drawn from time to time, through a special apparatus, and the degree of concentration is determined by ascertaining the specific gravity. When the milk shows the proper specific gravity, it is withdrawn and analyzed chemically. If the chemical analysis reveals a deviation from that desired, it is standardized.

Evaporated and condensed milks that are canned are first homogenized, and then the cans are filled and sealed. The canned milk is then sterilized by heating it with steam under pressure. After sterilization the cans are shaken vigorously to break up the coagulated proteins.

In making sweetened condensed milks the necessary sugar is added to the milk in the hot well. Normally from 14 to 20 pounds of sugar is added per 100 pounds of fluid milk.

DRIED MILK

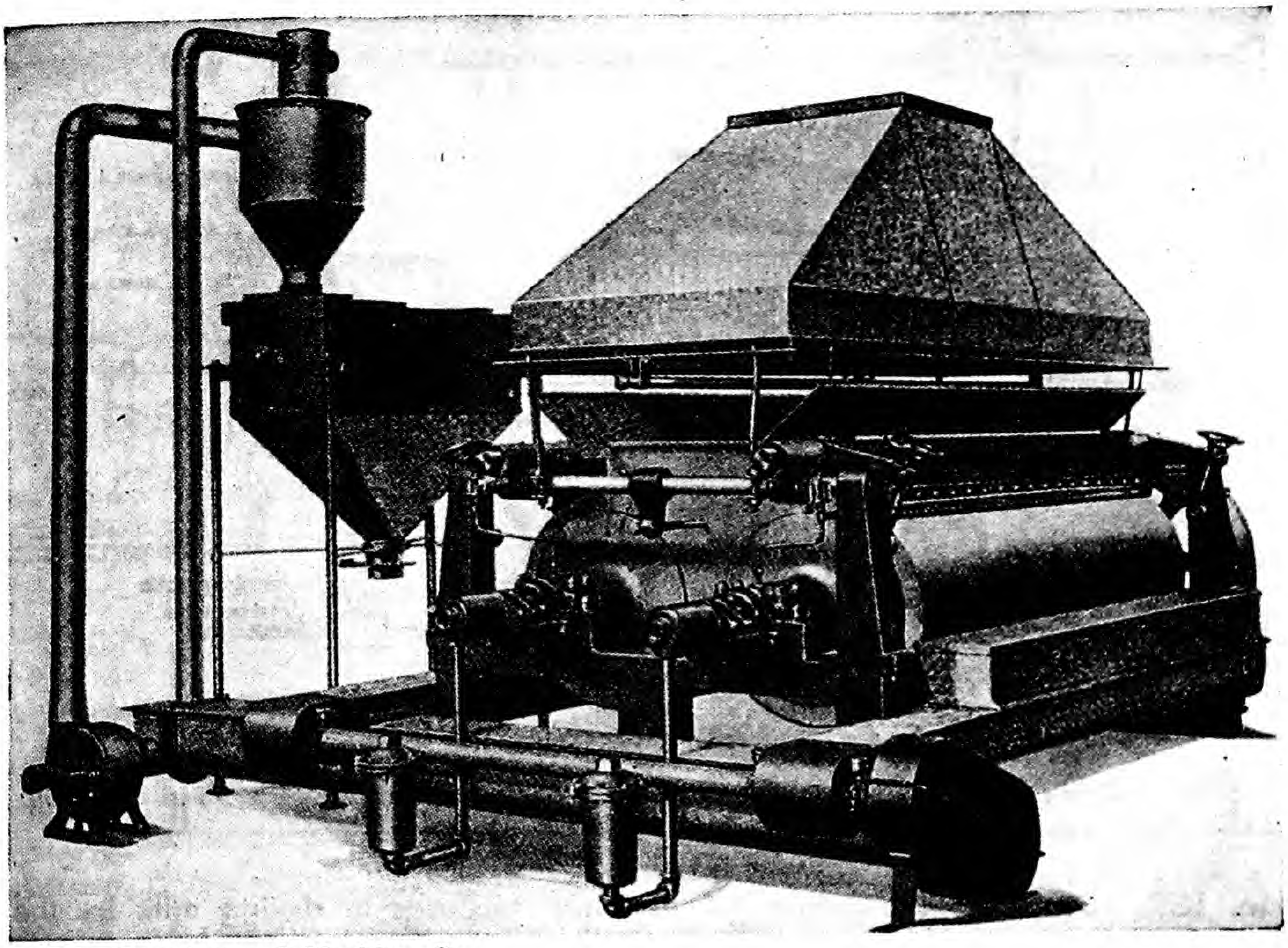
While commercial production of dried milks or milk powder is a comparatively new venture, the art of drying milk is an old one. Marco Polo described the making and use of dried milk by Tartan soldiers in the thirteenth century. The milk was first boiled to a paste and then was spread outdoors to be dried to a powder by the sun. Each soldier on march carried 10 pounds of this powder, which he remade by mixing it with water and used for food. The modern making of dried milk began in a small way in this country in 1898. Since that time, the production of dried milk and milk products has increased at a rapid rate.

While milk has been dried by freezing and the so-called dough process in which milk is first concentrated to a dough by heat, modern dried milk is produced by one of three general processes—the drum process, the spray process, and the continuous band or flake film driers.

Processes Used

The drum process. The drum process or film drying system of drying milk was adapted from a similar system for drying gelatin. While there are several different types of drum driers, the chief feature common to all of them is a revolving hollow steel drum heated from the inside with steam. A thin film of milk is dried upon the outer surface of the drum and scraped off by means of a scraper knife. The sheets of dry milk are then ground into a fine powder. The drum drying system is the most economical means of drying milk, from the standpoint of both investment costs and costs of operation.

There are a large number of patented modifications of drum driers, all of which can be grouped into three different classes. These are: (1) the atmospheric drum drier, (2) the vacuum drum drier, and (3) the spray driers. In addition to the different types of machines there are also different processes of manufacture. These processes may be classified as fol-



Buffalo Foundry and Machine Co.

Fig. 138. An atmospheric drum dryer.

lows: (1) drying the straight fluid milk, (2) condensing the milk before drying, and (3) whipping the condensed milk before drying.

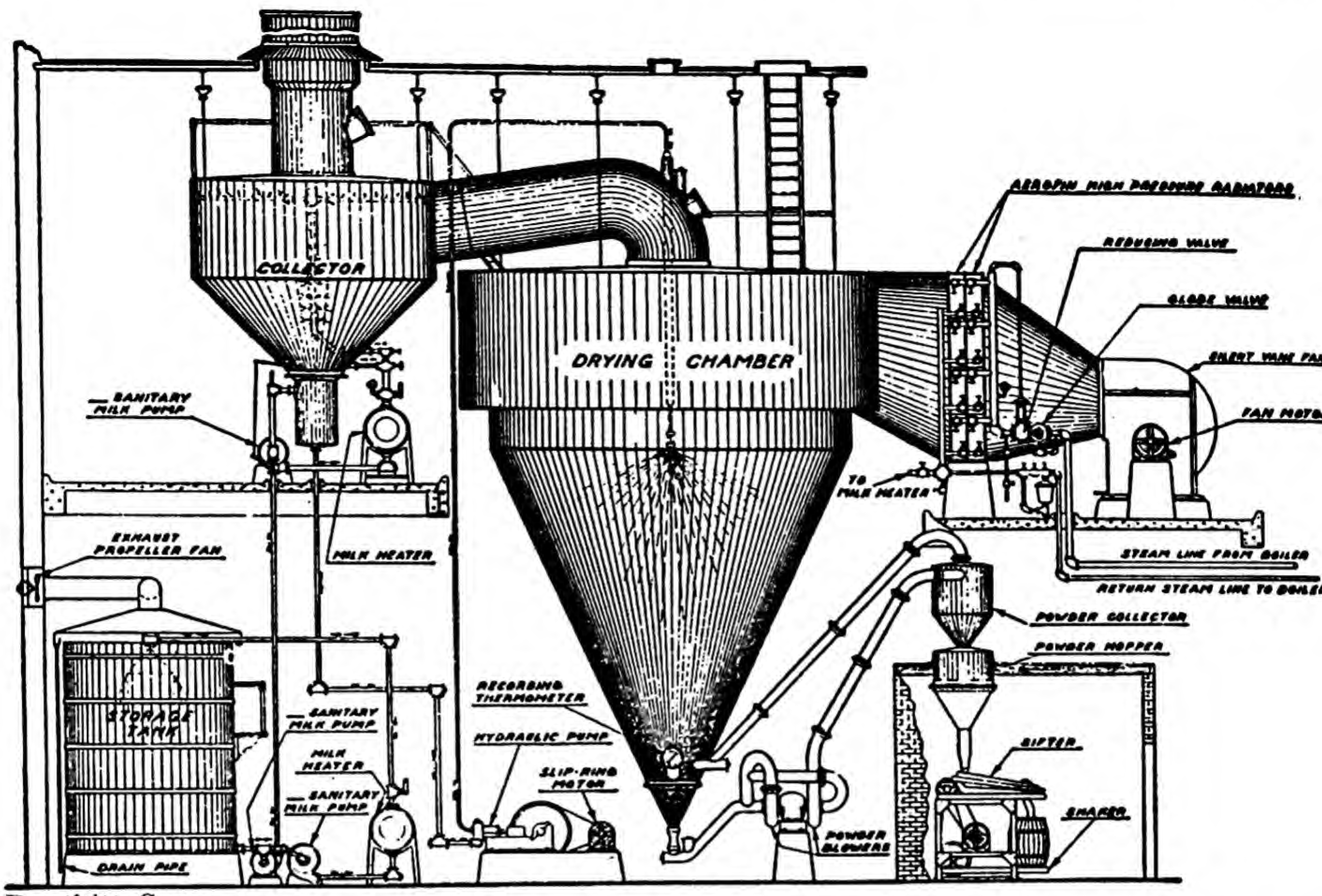
The atmospheric drum drier consists of one or two drums operating in normal atmospheric pressure. The temperature of course must be high to drive off the water, and unless conditions are carefully controlled, the dried film may burn. Too thin films of milk on the drum and too high steam pressures may be the cause of burning. Too thick a milk film or too low steam pressure causes insufficient drying. (Fig. 138.)

Vacuum drum driers. In order to lower the temperature for driving the water off the film of milk on the drum, the whole is encased in an airtight compartment, and the air pressure is reduced by vacuum pumps. The powder produced by this method is more soluble than that produced on the atmospheric pressure drums.

The spray drum method is really a modification of the vacuum drum process in which the milk film is sprayed on the drum. In the other methods the milk film is dipped onto the drum. (Fig. 139.)

Treatment of milk. While the milk may be dried without any treatment except heating before it comes in contact with the hot revolving drums, it may also be concentrated in a vacuum pan before drying. By condensing the milk before drying a large portion of the water is expelled, and the capacity of the machine is greatly increased.

When whole milk and cream are dried by the drum process, these



Douthitt Corp.

Fig. 139. Diagram illustrating the essential features in drying milk by the spray process.

products should be homogenized before drying. Unless this is done, the fat will churn or oil off when the dried product is reconstituted.

The spray process. There are several different types of spray process driers, all alike in the essential features. The essential features common to all spray processes are facilities for spraying the milk in a fine mist, a large chamber into which the milk is sprayed, a blast of hot air into the drying chamber, and facilities for gathering the dried powder.

The hot air passing up through the fine mist of milk removes the water, and the dry particles fall to the bottom. The dried powder is then removed from the bottom to the chamber either by automatic appliances or "shoveled out" after operations have stopped.

The milk is usually condensed before being dried by this method.

The flake film process. The machine used consists of an endless wire mesh belt running through a tunnel through which passes a blast of hot air. The milk is condensed to a very high concentration of solids (45 to 55 per cent), and then is cooled and placed in a thin film upon the endless wire belt. As the milk passes through the tunnel, the hot air removes the moisture, and the dried product is removed from the belt.

A product of high solubility is made by whipping the highly condensed product into a fluffy consistency before it is placed upon the belt.

Kinds of dried milks. First, dried milks or milk products are designated according to the process by which they are made. These are (1) spray, (2) atmospheric drum dried, (3) vacuum drum dried, and (4) flake

film. Next dried milk and milk products are classified according to the product from which they are made, as follows:

Dry whole milk, as the term indicates, is made from whole milk with a normal fat per cent. It is made largely by the spray process.

Dry skim milk is made from skim milk. All processes are employed in making this product.

Dry buttermilk is made from either sweet cream or ripened cream buttermilk. For ripened cream buttermilk, only the drum process is used, while for sweet cream any process may be used.

Dry whey is made only by the spray process.

Dry cream, likewise, is made only by the spray process.

Malted milk is made from milk, malt extract of barley, and wheat flour. It was the first product dried in the United States.

Dried ice cream mix is usually made by the spray process.

Composition of dried milk and milk products. The composition of dried milk products varies with the composition of the product used for drying. According to a ruling by the United States Department of Agriculture, dried whole milk must contain at least 26 per cent of fat and not over 5 per cent of water. Dried skim milk by the same ruling must not contain over 5 per cent of moisture.

Dry whole milk varies within the following limits: protein, 26 to 33 per cent; fat, 26 to 29 per cent; lactose, 31 to 38 per cent; and ash, 5.6 to 6.3 per cent. Dried skim milk differs from dry whole milk in its lower fat content and correspondingly higher values for the other ingredients. The fat content of skim milk powder varies from less than 1 per cent to 1.5 per cent; protein, from 34 to 37 per cent; lactose, from 46 to 52 per cent; and ash, from 7.8 to 8.2 per cent.

The composition of dry buttermilk differs from that of skim milk in its higher fat content and phospholipid content and slightly lower values for the other ingredients. The fat in dry buttermilk varies from 3 to 7 per cent. Dried sour buttermilk has a lower lactose content than sweet buttermilk, with an increase in lactic acid. Dry cream is the most variable of the dried milk products. Its composition is dependent upon the richness of the cream dried. The protein varies from 10 to 20 per cent; fat, from 50 to 75 per cent; lactose, from 12 to 25 per cent; and ash, from 1.8 to 4 per cent.

Physical properties of milk powder. Milk powder consists of grains of various sizes, depending upon the process with which it was made or the fineness to which it is ground. The spray process powders are the finest from the standpoint of the size of particles.

The color of milk powders varies from a snowy white to a yellowish white of whole milk powders with fat of high carotene content. Overheated drum dried powders sometimes have somewhat of a brown color. Acid buttermilk powder is also somewhat dark in color.

Hygroscopic properties. Dry milk takes up moisture from the air to form a hard lump. This property of dry milk is one contributing largely to its deterioration.

Taste. Fresh dried milk has a pleasant sweet taste with a slightly cooked flavor. If dried buttermilk is made from sour buttermilk, it has a sharp acid taste. If it is made from sweet cream buttermilk, it is somewhat flat in taste.

Solubility. The ease and completeness with which dried milks go into solution in water is important. Dried milks vary greatly in this respect, depending upon the process and methods used in their manufacture. Spray process powders are nearly 99 per cent soluble; vacuum drum dried powders are somewhat less soluble; and atmospheric drum dried powders may be only 55 to 70 per cent soluble.

Reconstituted dried milk. Milk reconstituted from milk powder differs from natural milk in its taste and flavor and in its physical properties.

That reconstituted milk differs so much from natural milk is one of the chief obstacles to a more extensive use of dried milks. Reconstituted milks do not possess many of the characteristic flavors of natural milk and in addition have acquired the taste of heated milk. The natural milk flavors are probably driven off in the drying process, and the heat applied in drying is responsible for the heated milk flavor.

In addition to having a taste different from that of natural milk, reconstituted milk differs also in other properties. When it is subjected to rennet action, either a curd is not formed or it is soft. The drum dried powders when reconstituted are not coagulated by rennet, and the spray powders will form soft curd. Acid coagulation of reconstituted milk behaves in much the same way as rennet coagulation.

Keeping qualities of dried milk. Milk powders are subject to deterioration with age. High moisture and high temperatures are conducive to deteriorations resulting in lowered solubility and a number of off flavors. These effects are caused by enzyme and microorganism actions as well as by inorganic catalysts.

The off flavors are of two distinct kinds: those caused by action on the solids-not-fat, and those caused by changes in the fat. The former defects are formed in all kinds of milk powder, and the latter are limited to those powders having considerable fat. The nonfat defects are described as a musty or stale flavor and odor. The atmospheric drum-dried powders are more subject to the development of these flavors than the spray process powders. The off flavors and odors caused by the fat are rancidity and tallowness. Rancidity is due to an enzyme (lipase) present in the milk that has not been heated above 170° F. Spray process powders are, therefore, more subject to this defect than the drum-dried powders. Moisture is also necessary for this defect to develop. Tallowy flavor, caused by oxidation of the unsaturated fats, is the most common off flavor in dried milks. Light as well as high temperatures speed up oxidation.

Keeping the milk powders in a cold and dry place will prevent or greatly delay the onset of the undesirable flavors and odors that develop

with age. Milk powders packed in vacuum cans keep almost indefinitely.

Uses for dried milk. Dried milks are used extensively in both foods for man and animals. For animal foods, drum-dried skim milk and buttermilk are used exclusively. They are used directly as a feed for calves where the whole milk is sold, or are mixed in with other feeds for the feeding of poultry, swine, calves, dogs, and other animals. For human consumption, dried milks are used in ice cream, sausage making, prepared cake flours, bread, candy, cooking, and special drinks, and to a limited extent it is reconstituted and used.

Dried milks constitute one of the cheapest sources of food, and from a nutritional standpoint are one of the most complete foods available. This would indicate a much more extensive use of these products than is now experienced. Their wide use in the home in the preparation of other foods and as reconstituted milk would seem reasonable to expect. How far the use of dried milks can be extended in this way depends upon a number of factors. First a satisfactory packaging material must be developed that will prevent small packages from spoiling when kept in unfavorable places, and after that an extensive educational program will be needed to bring to the consumer the merits of the product.

Chapter 54

ICE CREAM AND OTHER DAIRY PRODUCTS

S. S. Rahi
Shenyas.

IN ADDITION TO THE DAIRY PRODUCTS PREVIOUSLY DISCUSSED THERE ARE A number of other products that are made from milk or that use varying quantities of different dairy products. Among the more important of these products are ice cream, casein, lactose albumin, lactoflavin, and fermented milks. These products will be considered briefly in the following pages.

ICE CREAM

It is not known when ice cream was first made. Sommer believes that ice cream, as it is known today, is the result of an evolution of five centuries' duration. During that time ice cream has evolved from probably a mixture of snow and cream to a great variety of complex mixtures made under carefully controlled conditions in elaborately equipped large modern ice cream factories. Under a discussion of ice cream is usually included not only the frozen products containing cream and dairy products, but also a number of other frozen food products made in ice cream plants. The physical properties, the composition, the classification, and the manufacture of ice cream will be briefly considered in the following paragraphs.

Composition of ice cream. Ice cream is a variable product from the standpoint of the amounts of its ingredients. All ice creams, however, possess some characteristics in common. Three sets of ingredients make up nearly all of the dry matter of most ice creams. These are fat, serum solids, and sugar. In addition to these most ice creams contain some such stabilizer as gelatin, a flavoring compound, and frequently some other solid such as eggs.

Fat. The fat of ice cream varies from 8 per cent to more than 20 per cent in special products. The various states have laws requiring minimum amounts of fat ranging from 8 per cent to 14 per cent. The fat is secured from cream or reemulsified sweet cream butter.

Serum solids. Serum solids or milk solids-not-fat refer to the lactose, protein, and solids other than fat which are present in milk or cream. The amounts of serum solids vary from a minimum of 6 to 7 per cent to a maximum of 11 to 12 per cent. Serum solids are derived from the fresh milk and cream used, and also from condensed and dried milks.

Sugar. One of the chief characteristics of ice cream is a sweet taste. This is secured by the addition of sugar to form from 10 to 18 per cent of the mix. Sucrose is most commonly used, although glucose in the form of corn sugar is sometimes used as a source of part of the sweetness.

Stabilizers. In order to stabilize the ice cream mix and make a frozen product that has body and will stand up better, emulsion stabilizers are

added. Gelatin is the most common stabilizer, but various gums such as gum arabic and patented compounds are also used. When gelatin is used, from 0.1 to 0.6 per cent is added to the mix. In some states the amount of gelatin that may be used is limited by law.

Flavoring materials. Nearly all ice cream is flavored. Vanilla extract, chocolate, coffee, and extracts of fruits or crushed fruits are commonly used for this purpose. Nuts and such extracts as maple, rum, etc., are also used.

Other solids. Eggs, either natural or dried, are frequently used in fancy ice creams and sometimes in the commercial product. Eggs give added body to ice creams and to a certain extent may replace the stabilizers. Eggs may be added so that their solids make up from 0.1 to 1.0 per cent of the total mix.

Total solids. All the solids, including the fat, are known as total solids. A good market quality of ice cream contains 39 to 41 per cent of total solids. Rich ice creams may contain as much as 45 per cent of total solids. Homemade ice creams usually contain not more than 37 per cent total of solids unless they contain more than 14.0 per cent of fat.

Physical properties of ice cream. While ice creams vary greatly in composition, they consist of frozen products containing milk fat and other solids into which air is incorporated. Ice cream is, therefore, a double emulsion consisting of an emulsion of fat in water into which air is emulsified. The amount of air incorporated increases the volume of the product. The amount of increase in volume is called overrun. This is calculated on the basis of per cent in terms of the volume of the mix. If the weight of a given volume of the frozen product is only one-half that of the mix, the volume is doubled and the overrun is 100 per cent. An overrun of 95 per cent is quite common.

Not all of the water in ice cream is frozen in the normally frozen product. Because of the sucrose and glucose in solution some of the water remains in the liquid state even at much lower temperatures than are used for freezing ice cream. At the low temperatures required for freezing, two tendencies for crystal formation are present. One is for ice crystals to form, and the other is for the sugar to crystallize. Either of these crystallizations will make an ice cream of undesirable texture. High serum solids tend to bind the water and inhibit either sugar of ice crystal formation, imparting to the ice cream what is generally known as smoothness—a highly desirable characteristic.

Classification of ice cream. Different authorities classify ice creams in different ways. According to Sommer ice creams and ices may be divided into the following ten groups:

1. Plain ice cream
2. Fruit ice cream
3. Nut ice cream
4. Bisque ice cream
5. Mousse
6. Pudding
7. Custard
8. Parfait
9. Ices
10. Sherbets

Plain ice cream is ice cream of normal composition with or without the common flavoring. Fruit or nut ice creams are plain ice creams to which fruits or nuts have been added. Bisque ice cream is a plain ice cream mix with dried bread crumbs, "grapenuts," macaroons, marshmallows, or sponge cake added.

Mousse is frozen whipped cream.

Puddings consist of rich ice creams to which are added eggs and an assortment of fruits or nuts. Parfait is the same as pudding except that fruits and nuts are not used. Custards are mostly homemade products consisting of milk, eggs, and starch to which are added the sugar, cream, and flavoring.

Ices consist of frozen fruit juices. Sherbets are ices to which have been added milk, skim milk, or some other milk product.

Making ice cream. Ice cream making may be divided into two phases —preparation of the mix, and freezing.

Preparing the mix. In preparing the mix there are four important steps. These are: calculating the mix, pasteurizing, homogenizing, and aging.

Knowing the desired composition of the mix and the composition of the different ingredients entering into the mix, it is possible to calculate how much of each ingredient is to be used. Simultaneous algebraic equations are used in the solution of these problems.

In the production of commercial ice cream the mix is nearly always pasteurized to facilitate mixing. Pasteurizing is carried out as for milk. Following pasteurization, while the mix is still hot it is passed through a homogenizer, and then it is cooled to below 40° F. Homogenization not only reduces the size of the fat particles so that churning will be avoided in the freezing process, but also adds to the viscosity of the mix.

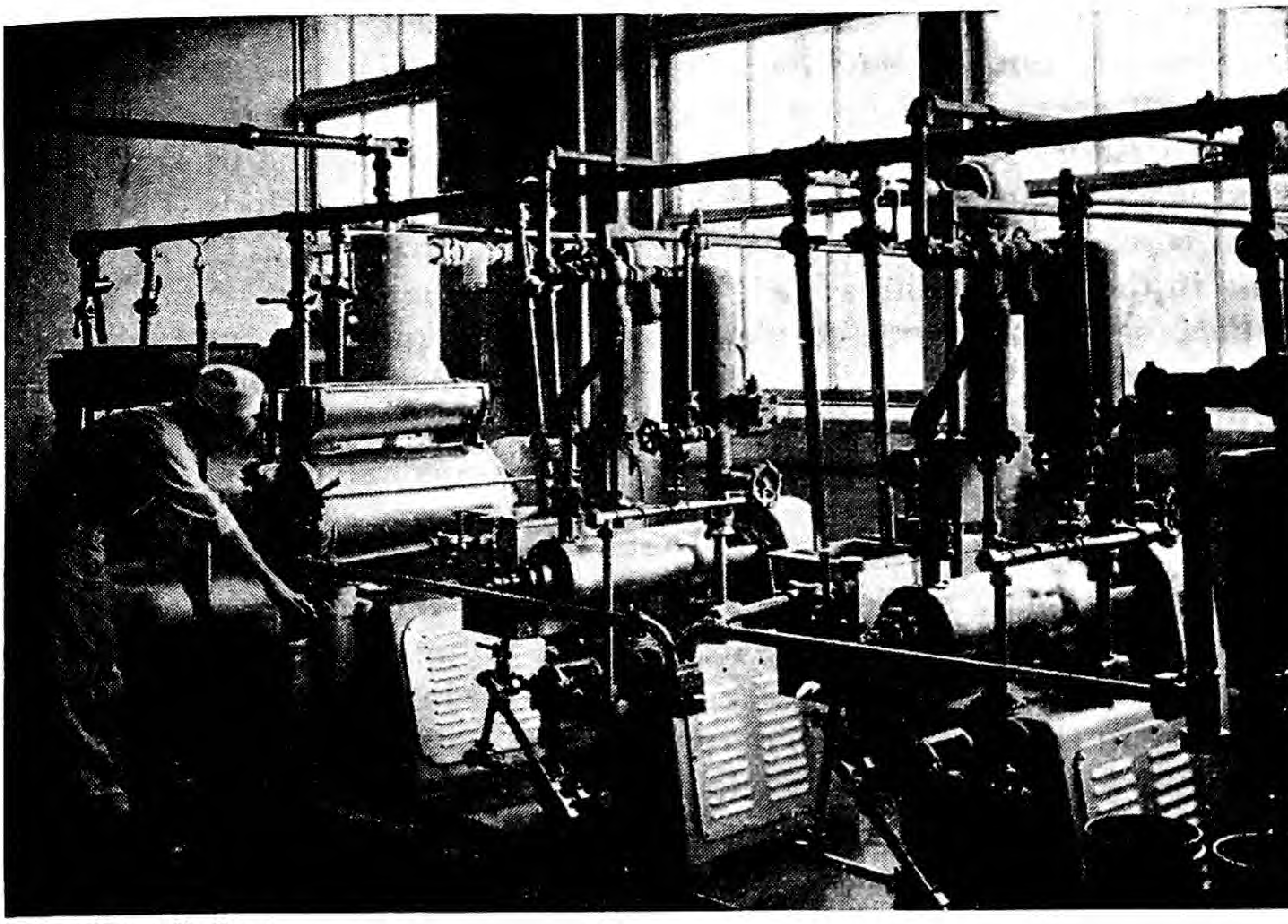
After homogenization the mix is aged before freezing. This is accomplished by letting it stand in a cool place for up to 24 hours and sometimes more. Aging brings about an increase in viscosity; this is desirable as it will secure a good whip and overrun.

Homemade mixes may be made up to the same composition as commercially made mixes but cannot be homogenized.

Freezing. Freezing ice cream to the consistency suited for consumption requires two stages. The first is freezing in a machine with agitation, and the second is hardening in a special cold room when packed.

Machine freezing may be accomplished by batch freezers or continuous freezers. The cold for freezing may come from salted ice used in the home freezer, or from cold brine or direct expansion of ammonia in the freezers used in commercial plants. (Fig. 140.)

In the batch freezers the freezing chamber is filled to less than half its total capacity to allow for expansion due to the incorporation of air during freezing. The inside dasher or agitator is set in motion, and the cold is turned on. When the mix has become thickened due to freezing, the cold is turned off, but the agitation is continued to incorporate the required amount of air. This point is determined by frequent tests. When



Cherry-Burrell Corp.

Fig. 140. A battery of ice cream freezers. The two in the foreground are of the continuous type, while the one being drained is a batch freezer.

the proper overrun has been secured, the frozen semi-solid mix is drained and packed, and is then set in a hardening room where it is held at below 0° F.

For freezing by the hand freezers the container should never be more than half full in order to allow for expansion with the incorporation of air. Finely chopped ice mixed with coarse salt at the rate of 6 pounds to 1 pound of salt should be packed around the freezer to the top. The dasher should be turned slowly until the mix is semisolid in consistency; then the turning should be rapid to incorporate air. Usually the freezer should be repacked with salt and ice and allowed to set for 30 minutes to 1 hour for the mix to harden.

The continuous freezer freezes a small stream of ice cream mix into which air is pumped as it passes by in the cold chamber.

Packaging ice cream. Ice cream is packaged in a variety of ways. Most ice cream, however, is either packaged in bulk or in bricks. An increasing amount is put up in fancy forms, such as highly decorated cakes or pies, or in individual forms in shapes of fruits, animals, and other objects.

Bulk ice cream is packaged in 1, 2, 3, 5, and 10 gallon cans from which it is dipped when used. The frozen mix is run into these cans directly from the freezer, and is hardened in them in the hardening room.

Brick ice cream is drawn from the freezer into long narrow metal

trays in which it is hardened. After it is hardened, the frozen ice cream is removed from the tray and cut into the brick size, usually one quart. Brick ice cream may be of different colored layers, or it may have a center design. The layers are secured by partly filling the trays with one kind of ice cream and following with layers of different kinds. The center form is secured by placing a previously hard frozen form of the desired kind in the semi-solid mix as it is drawn from the freezer.

Pies, cakes, and large forms of ice cream require experts to produce them. The center ice cream base is usually hardened in an appropriate form. The decorative work is done by hand. Individual forms are made by hardening the ice cream in molds of the proper shape.

CASEIN

Casein is used in commerce for a number of different products. Many objects resembling marble or ivory, such as buttons, combs, and toilet articles, are made from rennet coagulated casein. Casein is also used extensively in the making of waterproof glues, paper sizing, spreaders, and adhesives for paints and insecticides, and for various other uses. Casein is prepared by three different general methods—rennet coagulation, added acid coagulation, and natural lactic acid fermentation.

Rennet coagulated casein is coagulated by rennet in much the same way that cheese is produced. The product, while generally called rennet casein, is really calcium paracaseinate. The rennet curds are washed several times in cold water to get rid of as much of the soluble products of the milk as possible, and are then pressed and dried. The drying is effected by setting the shallow trays in which the curds are placed in a tunnel through which is blown a blast of warm air.

Natural acid casein is produced by adding starter to skim milk and setting it at 70 to 75° F. until the acid develops to form a firm curd. The curd is cut, and the curd and whey are then heated to about 100° F. to toughen it. The whey is drained off, and the curd is washed 3 or 4 times in cold water. After the excess water is squeezed out, the curd is dried in tunnels with warm blasts of air.

The artificially coagulated curd is formed with either hydrochloric or sulphuric acids. Great care must be exercised in adding these acids; they must not be added too rapidly, nor in too great amounts. If the acid is added too rapidly curd particles are suddenly formed that enclose other milk ingredients. If too much acid is added the casein is peptized and much of it is lost. In acid coagulation the milk should be tested frequently for the *p*H. A *p*H of 4.6 at 70° F. furnishes the best conditions for coagulation. Hydrochloric acid is usually considered superior to sulphuric acid for coagulation. The best method of using these acids is to spray them into the milk while it is agitated.

From 2.5 to 3.4 pounds of dry casein may be produced from 100 pounds of skim milk. The yield is dependent upon the casein content of the milk and the efficiency in making.

Quality in casein is secured by rigorous adherence to all the details in

the making process. Incorporation of fat, albumin, or other milk ingredients makes a casein of inferior quality for most uses. Incomplete washing has somewhat the same effect. Application of high heat either to the curd in the whey or in the drying process lowers the quality of the casein.

LACTOSE

Lactose, used in medicinal and food products, is made primarily from whey. The fat and bits of remaining casein are removed by centrifuging. The whey is then acidified with acetic acid and boiled to coagulate the albumin, which is filtered off. The phosphates are removed with lime, and the excess lime is removed with CO_2. The whey is then concentrated to 65 per cent solids and the milk sugar crystallized by cooling with cold water. The crystallized sugar is removed by centrifuging in regular sugar centrifuges. It is first washed with cold water, and is then clarified. This is done by dissolving it in water to which bone black is added, and filtering the solution. The syrup is then condensed, and the sugar is recrystallized, centrifuged again, and dried and ground.

FERMENTED MILKS

Probably one of the oldest milk products used by man was naturally fermented milk or the curd from fermented milk. Fermented milks of various types are still used all over the world. They are consumed because the sour flavor is pleasing to many and for their therapeutic value in changing the bacterial flora of the digestive tract. A discussion of the more important fermented milks follows:

Cultured buttermilk. This product is made from skim milk ripened from fresh milk by butter starter. The starter contains two organisms, *Streptococcus lactis* and *Streptococcus citrovorus.* Whole milk or partly skimmed milk is also used.

Bulgarian buttermilk. Bulgarian buttermilk is made from fresh skim milk, partly skimmed milk, or whole milk by the use of a special starter. The starter contains *Lactobacillus bulgaricus.*

Acidophilus milk. The bacterium, *Lactobacillus acidophilus*, when properly cultured in fresh milk produces a product that is relatively high in acid content. The use of this milk is frequently advised by physicians as a therapeutic agent in control of certain intestinal disturbances. By using acidophilus milk the acidophilus bacteria come to dominate the intestinal flora and suppress putrefactive types. The making of acidophilus milk requires special skill. Only a few laboratories with well trained men and proper equipment are able to make this product on a commercial scale.

Kumiss. This is an acid alcoholic milk beverage used principally in Russia and Asia. It is produced by the action of both bacteria and yeast. The bacteria produce lactic acid, and the yeast produces alcohol.

Kefir. Kefir resembles Kumiss in that both lactic acid and alcohol are produced and that it is used in the same general territory. It differs from

Kumiss in that the culture is transferred by what is known as "Kefir grains." These grains consist of adhered masses of small beadlike bodies which contain both the yeast and the acid producing bacteria.

Yoghurt. This is a sour milk which is practically free from alcohol, and which is formed through fermentation mainly by bacteria belonging to the group *Lactobacillus bulgaricus*. Yoghurt originated in the Balkans and is used extensively by the people living there. In the Balkans Yoghurt is frequently boiled down and is eaten as a semisolid food.

Lange-melk. Lange-melk typifies several fermented milks used in the Scandinavian countries. This milk is fermented by an acid producing organism and an organism that produces a ropy condition.

Sour cream. Sour cream or cultured cream is a cream soured, usually with butter culture, so as to produce a clean acid flavor and a heavy consistency. The fat content varies from 18 to 22 per cent. For the best product the cream is first pasteurized, then homogenized, cooled to 70° F., and starter added to bring the acidity up to 0.6 per cent in about 12 hours. After the proper acidity is developed the cream is cooled to below 40° F. and held for 12 to 24 hours.

Sour cream finds a good demand among some peoples, especially Jews and Slavs. It is used as a spread for bread and as a base for salads and other dishes.

Sour cream may be produced by merely letting good clean cream set at about 70° F. until the desired acidity develops. The resulting product is not as smooth nor as clean in flavor as the product produced as stated above.

APPENDIX

TABLE I

DAILY MAINTENANCE REQUIREMENTS OF DAIRY COWS[1]

Weight	Digestible Crude Protein	Total Digestible Nutrients	Calcium	Phosphorus
Pounds	*Pounds*	*Pounds*	*Grams*	*Grams*
800	.51	5.60	16.00	8.00
850	.54	5.95	17.00	8.50
900	.57	6.30	18.00	9.00
950	.60	6.65	19.00	9.50
1,000	.63	7.00	20.00	10.00
1,050	.66	7.35	21.00	10.50
1,100	.69	7.70	22.00	11.00
1,150	.72	8.05	23.00	11.50
1,200	.76	8.40	24.00	12.00
1,250	.79	8.75	25.00	12.50
1,300	.82	9.10	26.00	13.00
1,350	.85	9.45	27.00	13.50
1,400	.88	9.80	28.00	14.00
1,450	.91	10.15	29.00	14.50
1,500	.95	10.50	30.00	15.00

The digestible protein and total digestible nutrient requirements for varying amounts of milk of different fat contents are given in Table II. The calcium and phosphorus requirements for milk are given in Table III. The digestible protein, total digestible nutrient, calcium and phosphorus contents of common feeds are given in Table IV.

[1] GULLICKSON AND FITCH. Minn. Expt. Sta. Bul. 118. 1938.

TABLE II

Nutrients Required for Producing Milk in Addition to Amount Required for Maintenance

Note: Use the nearest percentage of fat given.

Per Cent of Fat in Milk 3.0			Per Cent of Fat in Milk 3.5		
Amount of Milk	Digestible Protein	Total Digestible Nutrients	Amount of Milk	Digestible Protein	Total Digestible Nutrients
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1	0.040	0.277	1	0.042	0.306
5	0.201	1.386	5	0.211	1.528
10	0.402	2.771	10	0.422	3.056
20	0.804	5.542	20	0.844	6.112
30	1.206	8.313	30	1.266	9.168
40	1.608	11.084	40	1.688	12.224
50	2.010	13.855	50	2.110	15.280
60	2.412	16.625	60	2.532	18.336
Per Cent of Fat in Milk 4.0			Per Cent of Fat in Milk 4.5		
1	0.0462	0.3354	1	0.0491	0.3641
5	0.231	1.677	5	0.246	1.821
10	0.462	3.354	10	0.491	3.641
20	0.924	6.708	15	0.737	5.462
30	1.386	10.062	20	0.982	7.282
40	1.848	13.416	30	1.473	10.923
50	2.310	16.770	40	1.964	14.564
60	2.772	20.124	50	2.455	18.205
Per Cent of Fat in Milk 5.0			Per Cent of Fat in Milk 5.5		
1	0.0518	0.3905	1	0.0548	0.4157
5	0.259	1.955	5	0.274	2.079
10	0.518	3.905	10	0.548	4.157
15	0.777	5.858	15	0.822	6.236
20	1.036	7.810	20	1.096	8.314
25	1.295	9.763	25	1.370	10.393
30	1.554	11.715	30	1.644	12.471
40	2.072	15.620	40	2.192	16.628
Per Cent of Fat in Milk 6.0			Per Cent of Fat in Milk 6.5		
1	0.0573	0.4416	1	0.0618	0.4693
5	0.287	2.208	5	0.309	2.347
10	0.573	4.416	10	0.618	4.693
15	0.860	6.624	15	0.927	7.040
20	1.146	8.832	20	1.236	9.386
25	1.433	11.040	25	1.545	11.733
30	1.719	13.248	30	1.854	14.079
40	2.292	17.664	40	2.472	18.772

TABLE III

Approximate Amounts of Calcium and Phosphorus That Should Be Provided for Milk Production[1]

Milk	Calcium	Phosphorus
Pounds	*Grams*	*Grams*
1	.85	0.70
5	4.25	3.50
10	8.50	7.00
15	12.75	10.50
20	17.00	14.00
25	21.25	17.50
30	25.50	21.00
35	29.75	24.50
40	34.00	28.00
45	38.25	31.50
50	42.50	35.00
60	51.00	42.00

The maintenance requirements for calcium and phosphorus for varying weights of cows are given in Table I. The average phosphorus and calcium contents of various feeds are given in Table IV. There is no evidence that large excesses of calcium and phosphorus are injurious to dairy cattle although the sum of the requirements for milk production and maintenance are entirely adequate. When milking cows are fed relatively small amounts of low calcium roughages, such as timothy hay and large amounts of concentrates, the calcium content of the ration is apt to be inadequate.

[1] Ibid.

Table IV

Average Amounts of Digestible Nutrients and Calcium and Phosphorus in 100 Pounds of Common Ffeds[1]

	Digestible Protein	Total Digestible	Calcium	Phosphorus
Concentrates	*Pounds*	*Pounds*	*Grams*	*Grams*
Barley	9.7	77.1	21.8	144.2
Coconut oil meal	18.5	82.5	—	—
Corn, dent	7.3	81.5	4.5	107.8
Corn and cob meal	6.1	78.1	—	—
Corn gluten feed	22.5	78.0	72.1	368.3
Corn gluten meal	37.7	80.5	39.0	189.2
Cottonseed meal (43% protein)	37.6	80.2	—	—
Cottonseed meal (40% protein)	33.5	73.6	86.5	511.2
Cottonseed meal (below 36% protein)	26.1	65.6	—	—
Distillers' grains from corn	21.9	84.5	—	—
Distillers' grains from rye	12.0	64.5	—	—
Dried beet pulp	5.3	73.7	328.0	42.2
Dried beet pulp with molasses	6.9	72.7	247.3	27.7
Dried brewers' grains	24.0	66.8	128.4	235.4
Dried skim milk	33.6	85.2	563.4	427.7
Feterita	9.9	79.2	—	—
Flaxseed	20.6	102.8	115.2	297.1
Hominy feed	7.5	83.7	—	—
Kafir	9.2	80.0	—	—
Linseed oil meal (35.5% protein)	32.5	75.3	160.0	348.8
Malt sprouts	20.9	70.8	93.4	266.7
Molasses (beet)	2.9	58.7	23.0	9.5
Molasses (cane)	1.3	55.9	400.9	28.9
Oats	10.2	69.5	40.8	134.5
Peanut oil meal (45% protein)	41.0	82.5	—	—
Rye	9.1	81.9	23.4	194.6
Soybeans (ground)	33.7	92.3	91.0	271.0
Soybean oil meal	37.8	82.3	107.0	282.6
Wheat	8.8	79.2	16.6	159.8
Wheat bran	12.9	67.6	42.8	571.0
Wheat middlings	15.2	78.4	39.9	365.6
Dried Roughages				
Alfalfa hay (prebloom)	14.8	53.4	720.0	85.0
Alfalfa hay early cut	11.6	51.4	715.3	86.7
Alfalfa hay medium cut	10.4	51.5	586.9	92.1
Alfalfa hay late cut	9.6	48.7	428.2	102.1
Clover, alsike	7.9	47.3	360.0	97.0
Clover, red	7.4	49.6	541.6	81.6
Cowpea hay	13.1	49.8	—	—
Corn fodder	3.7	48.1	97.0	65.0
Corn stover	2.0	36.4	65.4	40.0
Kafir fodder	3.5	46.1	—	—
Lespedeza hay	10.0	51.3	—	—
Millet hay	4.5	49.0	—	—
Mixed hay (½ clover, ½ timothy)	5.1	49.3	366.1	76.5
Oat hay	4.7	45.5	—	—
Oat straw	1.0	45.6	161.9	64.9
Pea hay	10.3	52.2	—	—
Prairie hay	2.8	48.3	213.5	33.9
Red top hay	4.8	54.1	—	—
Reed canary grass hay	4.5	52.3	—	—
Soybean hay	7.9	50.0	430.9	115.6
Sudan grass hay	3.7	51.4	—	—
Sweet clover hay	10.9	50.7	548.9	93.0
Timothy hay	2.9	48.0	136.7	65.4
Vetch hay	9.1	52.4	—	—
Wheat straw	0.7	36.9	106.6	40.4
Succulent Feeds and Miscellaneous				
Alfalfa silage (average water)	4.0	16.0	—	—
Corn silage	1.2	16.8	31.0	30.0
Sunflower silage	1.0	13.7	163.7	19.3
Corn cannery silage	1.1	17.8	—	—
Pea cannery silage	2.8	15.3	—	—
Potatoes	1.1	17.3	—	—
Beets	1.3	11.5	—	—
Mangels	1.0	6.5	32.5	17.8
Rutabagas	1.0	9.5	39.0	21.8
Skim milk	3.5	8.7	63.6	54.5
Whole milk	3.3	16.2	54.9	45.2
Bonemeal (Minerals only)			13,105.0	5,967.0
Limestone (Minerals only)			18,144.0	—

[1] Data taken from Minn. Agr. Expt. Sta. Bul. 218 and various Experiment Station publications. For feeds not listed in this table see Morrison, *Feeds and Feeding.*

TABLE V

CONSTANTS FOR EVALUATING FEEDS. THE CONSTANTS BY WHICH THE PRICES OF COTTONSEED MEAL (43% PROTEIN) AND CORN, RESPECTIVELY, MUST BE MULTIPLIED AND THE PRODUCTS ADDED (OR SUBTRACTED WHEN PRECEDED BY A — SIGN) TO GIVE THE VALUES OF COMMON FEEDS

CONCENTRATES

	Constant	
	For Cottonseed Meal	For Corn
Barley	.103	.852
Coconut oil meal	.419	.612
Corn and cob meal	—.033	.989
Corn gluten feed	.576	.437
Corn gluten meal	1.133	—.035
Cottonseed feed (below 36% protein)	.723	.141
Distillers' grains from corn	.513	.570
Distillers' grains from rye	.179	.507
Dried beet pulp	—.049	.948
Dried beet pulp with molasses	.014	.879
Dried skim milk	.900	.195
Feterita	.103	.901
Flaxseed	.423	.879
Homing feed	.009	1.051
Kafir	.070	.931
Linseed oil meal (35.5% protein)	.957	.060
Malt sprouts	.538	.380
Molasses cane	—.138	.811
Oats	.147	.719
Rye	.065	.946
Soybeans	.945	.279
Soybean oil meal	1.131	—.011
Wheat	.134	.915
Wheat bran	.254	.600
Wheat middlings	.303	.688

ROUGHAGE

Alfalfa prebloom	.315	.346
Alfalfa early cut	.260	.396
Alfalfa medium	.215	.438
Alfalfa late cut	.194	.422
Clover, alsike	.136	.458
Clover, red	.109	.510
Cowpea hay	.326	.227
Corn fodder	—.023	.611
Corn stover	—.047	.489
Kafir fodder	.039	.390
Lespedeza	.217	.370
Millet	.006	.585
Mixed hay	.025	.580
Oat hay	.023	.525
Oat straw	—.115	.663
Pea hay	.168	.623
Prairie hay	—.057	.644
Red top hay	.002	.661
Reed canary grass hay	.017	.624
Soybean hay	.127	.499
Sudan grass hay	—.027	.650
Sweet clover hay	.236	.409
Timothy hay	—.053	.636
Vetch hay	.147	.498
Wheat straw	—.098	.545

SILAGES, ETC.

Alfalfa silage	.073	.173
Corn silage	—.011	.217
Sunflower silage	—.009	.176
Pea cannery silage	.053	.140
Corn cannery silage	—.018	.235
Potatoes	—.014	.151
Beets	.009	.131
Mangels	.015	.066
Rutabagas	.008	.110
Skim milk	.091	.019
Whole milk	.061	.108

TABLE VI

ESTIMATED WEIGHTS OF SILAGE PER CUBIC FOOT AT VARIOUS DEPTHS AND CAPACITIES OF SILOS [1]

Depth of Silage, Feet	Estimated Weight of Silage to the Cubic Foot at This Depth	Average Weight of Silage to the Cubic Foot to This Depth	10 ft. Diameter	12 ft. Diameter	14 ft. Diameter	16 ft. Diameter	18 ft. Diameter	20 ft. Diameter
	Pounds	*Pounds*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1	32.0	32.0	1.26	1.81	2.46	3.22	4.07	5.03
2	32.7	32.4	2.54	3.66	4.98	6.51	8.23	10.17
3	33.4	32.7	3.85	5.54	7.55	9.86	12.46	15.40
4	34.1	33.1	5.19	7.48	10.19	13.31	16.81	20.79
5	34.8	33.4	6.55	9.45	12.85	16.78	21.21	26.22
6	35.4	33.7	7.94	11.44	15.56	20.32	25.68	31.75
7	36.0	34.1	9.37	13.50	18.37	23.99	30.31	37.48
8	36.6	34.4	10.80	15.56	21.19	27.66	34.95	43.21
9	37.4	34.7	12.26	17.66	24.04	31.39	39.66	49.03
10	38.0	35.0	13.74	19.79	26.95	35.18	44.45	54.95
11	38.4	35.3	15.25	21.95	29.89	39.02	49.31	60.96
12	38.8	35.6	16.77	24.15	32.89	42.93	54.25	67.07
13	39.2	35.9	18.32	26.38	35.93	46.90	59.27	73.27
14	39.6	36.2	19.90	28.65	39.02	50.93	64.36	79.57
15	40.0	36.4	21.44	30.88	42.04	54.87	69.34	85.72
16	40.2	36.7	23.05	33.21	45.21	59.01	74.57	92.19
17	40.4	36.9	24.63	35.47	48.30	63.04	79.67	98.49
18	40.6	37.1	26.22	37.76	51.42	67.11	84.81	104.84
19	40.8	37.3	27.83	40.07	54.56	71.22	90.00	111.27
20	41.0	37.5	29.45	42.41	57.75	75.38	95.25	117.75
21	41.2	37.6	31.00	44.65	60.79	79.35	100.28	123.97
22	41.4	37.8	32.65	47.02	64.03	83.58	105.61	130.56
23	41.6	38.0	34.32	49.41	67.29	87.84	110.50	137.22
24	41.8	38.1	35.90	51.70	70.40	91.90	116.13	143.56
25	42.0	38.3	37.60	54.15	73.72	96.23	121.60	150.33
26	42.2	38.4	39.20	56.46	76.87	100.34	126.80	156.75
27	42.4	38.6	40.92	58.94	80.24	104.74	132.36	163.63
28	42.6	38.7	42.55	61.28	83.43	108.90	137.62	170.13
29	42.8	38.9	44.30	63.79	86.86	113.37	143.27	177.11
30	43.0	39.0	45.94	66.08	90.09	117.59	148.59	183.69

Corrections to the above weights are to be made for conditions as follows:

1. When the corn is less mature than usual (kernels in the beginning of dough stage) add 10 to 15 per cent.
2. If the grain yield is unusually large add 5 to 10 per cent.
3. When the corn is more mature and contains less water deduct 10 to 15 per cent.
4. When the corn contains little or no grain deduct 10 per cent.

[1] Mo. Agr. Expt. Sta. Bul. 164.

TABLE VII

BUTTERFAT FEED PRICE RATIOS, UNITED STATES BY MONTHS[1]

Year and Month	Price Ratio	12 Month Moving Total	24 Month Moving Total	12 Month Moving Average Centered	Actual 12 Month Moving Average
1918:					
January	19.8	206.3	410.9	17.1	115.8
February	18.3	207.9	414.2	17.3	105.8
March	16.0	211.0	418.9	17.5	91.4
April	15.4	215.2	426.2	17.8	86.5
May	16.0	220.3	435.5	18.1	88.4
June	16.1	226.7	447.0	18.6	86.6
July	16.6	228.7	455.4	19.0	87.4
August	17.0	230.4	459.1	19.1	89.0
September	19.9	236.1	466.5	19.4	102.6
October	22.0	242.7	478.8	20.0	110.0
November	23.9	246.5	489.2	20.4	117.2
December	25.7	248.5	495.0	20.6	124.8
1919:					
January	21.8	249.6	498.1	20.8	104.8
February	20.0	250.7	500.3	20.8	96.2
March	21.7	250.0	500.7	20.9	103.8
April	22.0	250.7	500.7	20.9	105.3
May	19.8	251.7	502.4	20.9	94.7
June	18.1	250.3	502.0	20.9	86.6
July	17.7	250.9	501.2	20.9	84.7
August	18.1	251.9	502.8	21.0	86.2
September	19.2	250.9	502.8	21.0	91.4
October	22.7	249.2	500.1	20.8	109.1
November	24.9	246.5	495.7	20.7	120.3
December	24.3	244.6	491.1	20.5	118.5
1920:					
January	22.4	243.8	488.4	20.4	109.8
February	21.0	244.4	488.2	20.3	103.4
March	20.7	247.7	492.1	20.5	101.0
April	20.3	251.6	499.3	20.8	97.6
May	17.1	257.9	509.5	21.2	80.7
June	16.2	263.5	521.4	21.7	74.7
July	16.9	272.1	535.6	22.3	75.8
August	18.7	280.2	552.3	23.0	81.3
September	22.5	291.1	571.3	23.8	94.5
October	26.6	301.8	592.9	24.7	107.7
November	31.2	307.2	609.0	25.4	122.8
December	29.9	311.8	619.0	25.8	115.9
1921:					
January	31.0	319.0	630.8	26.3	117.9
February	29.1	329.1	648.1	27.0	107.8
March	31.6	335.8	664.9	27.7	114.1
April	31.0	342.8	678.6	28.3	109.5
May	22.5	346.0	688.5	28.7	78.4
June	20.8	349.1	695.1	29.0	71.7
July	24.1	345.0	694.1	28.9	83.4
August	28.8	341.7	686.7	28.6	100.7

Table continued on next page

[1] Includes an allowance for dairy production payments, October 1, 1943 through June 30, 1946. Source is the Research and Analysis Division, Dairy Branch, PMA.

BUTTERFAT FEED PRICE RATIOS, UNITED STATES, BY MONTHS

(Continued)

Year and Month	Price Ratio	12 Month Moving Total	24 Month Moving Total	12 Month Moving Average Centered	Actual 12 Month Moving Average
1921 (*Cont.*)					
September	29.2	334.6	676.3	28.2	103.5
October	33.6	326.8	661.4	27.6	121.7
November	34.4	327.0	653.8	27.2	126.5
December	33.0	329.4	656.4	27.4	120.4
1922:					
January	26.9	329.8	659.2	27.5	97.8
February	25.8	324.9	654.7	27.3	94.5
March	24.5	322.0	646.9	27.0	90.7
April	23.2	316.6	638.6	26.6	87.2
May	22.7	312.1	628.7	26.2	86.6
June	23.2	311.6	623.7	26.0	89.2
July	24.5	314.1	625.7	26.1	93.9
August	23.9	315.8	629.9	26.2	91.2
September	26.3	318.0	633.8	26.4	99.6
October	28.2	321.9	639.9	26.7	105.6
November	29.9	322.6	644.5	26.9	111.2
December	32.5	321.2	643.8	26.8	121.3
1923:					
January	29.4	319.4	640.6	26.7	110.1
February	27.5	320.0	639.4	26.6	103.4
March	26.7	320.1	640.1	26.7	100.0
April	27.1	319.0	639.1	26.6	101.9
May	23.4	318.4	637.4	26.6	88.0
June	21.8	316.5	634.9	26.5	82.3
July	22.7	318.1	634.6	26.4	86.0
August	24.5	320.0	638.1	26.6	92.1
September	26.4	321.4	641.4	26.7	98.9
October	27.1	319.0	640.4	26.7	101.5
November	29.3	318.7	637.7	26.6	110.2
December	30.6	319.5	638.2	26.6	115.0
1924:					
January	31.0	318.2	637.7	26.6	116.5
February	29.4	313.5	631.7	26.3	111.8
March	28.1	307.2	620.7	25.9	108.5
April	24.7	300.1	607.3	25.3	97.6
May	23.1	291.2	591.3	24.6	93.9
June	22.6	282.6	573.8	23.9	94.6
July	21.4	272.5	555.1	23.1	92.6
August	19.8	262.5	535.0	22.3	88.8
September	20.1	256.7	519.2	21.6	93.1
October	20.0	255.0	511.7	21.3	93.9
November	20.4	254.5	509.5	21.2	96.2
December	22.0	253.7	508.2	21.2	103.8
1925:					
January	20.9	254.8	508.5	21.2	98.6
February	19.4	258.7	513.5	21.4	90.7
March	22.3	264.1	522.8	21.8	102.3
April	23.0	273.7	537.8	22.4	102.7
May	22.6	283.9	557.6	23.2	97.4
June	21.8	292.6	576.5	24.0	90.8
July	22.5	300.7	593.3	24.7	91.1

Table continued on next page.

Butterfat Feed Price Ratios, United States, by Months

(Continued)

Year and Month	Price Ratio	12 Month Moving Total	24 Month Moving Total	12 Month Moving Average Centered	Actual 12 Month Moving Average
1925 (*Cont.*)					
August	23.7	309.3	610.0	25.4	93.3
September	25.5	315.4	624.7	26.0	98.1
October	29.6	319.3	634.7	26.4	112.1
November	30.6	322.9	642.2	26.8	114.2
December	30.7	327.5	650.4	27.1	113.3
1926:					
January	29.0	331.1	658.6	27.4	105.8
February	28.0	333.1	664.2	27.7	101.1
March	28.4	335.3	668.4	27.8	102.2
April	26.9	334.9	670.2	27.9	96.4
May	26.2	336.1	671.0	28.0	93.6
June	26.4	339.1	675.2	28.1	94.0
July	26.1	342.4	681.5	28.4	91.9
August	25.7	346.0	688.4	28.7	89.5
September	27.7	350.0	696.0	29.0	95.5
October	29.2	354.9	704.9	29.4	99.3
November	31.8	356.6	711.5	29.6	107.4
December	33.7	354.3	710.9	29.6	113.9
1927:					
January	32.3	352.2	706.5	29.4	109.9
February	31.6	349.8	702.0	29.2	108.2
March	32.4	346.9	696.7	29.0	111.7
April	31.8	344.8	691.7	28.8	110.4
May	27.9	341.3	686.1	28.6	97.6
June	24.1	336.4	677.7	28.2	85.5
July	24.0	333.0	669.4	27.9	86.0
August	23.3	327.8	660.8	27.5	84.7
September	24.8	320.9	648.7	27.0	91.9
October	27.1	312.9	633.8	26.4	102.7
November	28.3	306.9	619.8	25.8	109.7
December	28.8	304.2	611.1	25.5	112.9
1928:					
January	28.9	302.6	606.8	25.3	114.2
February	26.4	305.8	608.4	25.4	103.9
March	25.5	309.5	615.3	25.6	99.6
April	23.8	311.1	620.6	25.9	91.9
May	21.9	312.0	623.1	26.0	84.2
June	21.4	312.8	624.8	26.0	82.3
July	22.4	311.9	624.7	26.0	86.2
August	26.5	312.8	624.7	26.0	101.9
September	28.5	314.9	627.7	26.2	108.8
October	28.7	318.1	633.0	26.4	108.7
November	29.2	323.5	641.6	26.7	109.4
December	29.6	329.0	652.5	27.2	108.8
1929:					
January	28.0	332.9	661.9	27.6	101.4
February	27.3	332.3	665.2	27.7	98.6
March	27.6	329.9	662.2	27.6	100.0
April	27.0	327.9	657.8	27.4	98.5
May	27.3	325.2	653.1	27.2	100.4
June	26.9	321.1	646.3	26.9	100.0

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BUTTERFAT FEED PRICE RATIOS, UNITED STATES, BY MONTHS

(Continued)

Year and Month	Price Ratio	12 Month Moving Total	24 Month Moving Total	12 Month Moving Average Centered	Actual 12 Month Moving Average
1929 (*Cont.*)					
July	26.3	316.0	637.1	26.5	99.2
August	25.9	311.2	627.2	26.1	99.2
September	26.1	306.3	617.5	25.7	101.6
October	26.7	303.1	609.4	25.4	105.1
November	26.5	299.3	602.4	25.1	105.6
December	25.5	293.3	592.6	24.7	103.2
1930:					
January	22.9	289.3	582.6	24.3	94.2
February	22.5	287.3	576.6	24.0	93.8
March	22.7	286.8	574.1	23.9	95.0
April	23.8	287.1	573.9	23.9	99.6
May	23.5	288.6	575.7	24.0	97.9
June	20.9	287.8	576.4	24.0	87.1
July	22.3	287.1	574.9	24.0	92.9
August	23.9	286.7	573.8	23.9	100.0
September	25.6	288.8	575.5	24.0	106.7
October	27.0	288.4	577.2	24.0	112.5
November	28.0	284.5	572.9	23.9	117.2
December	24.7	283.5	568.0	23.7	104.2
1931:					
January	22.2	283.6	567.1	23.6	94.1
February	22.1	287.5	571.1	23.8	92.9
March	24.8	293.9	581.4	24.2	102.5
April	23.4	304.3	598.2	24.9	94.0
May	19.6	307.3	611.6	25.5	76.9
June	19.9	312.3	619.6	25.8	77.1
July	22.4	315.4	627.7	26.2	85.5
August	27.8	316.1	631.5	26.3	105.7
September	32.0	314.0	630.1	26.3	121.7
October	37.4	311.8	625.8	26.1	143.3
November	31.0	312.3	624.1	26.0	119.2
December	29.7	311.9	624.2	26.0	114.2
1932:					
January	25.3	309.8	621.7	25.9	97.7
February	22.8	308.1	617.9	25.7	88.7
March	22.7	303.2	611.3	25.5	89.0
April	21.2	295.0	598.2	24.9	85.1
May	20.1	295.2	590.2	24.6	81.7
June	19.5	301.9	597.1	24.9	78.3
July	20.3	309.8	611.7	25.5	79.6
August	26.1	314.2	624.0	26.0	100.4
September	27.1	317.1	631.3	26.3	103.0
October	29.2	320.9	638.0	26.6	109.8
November	31.2	326.7	647.6	27.0	115.6
December	36.4	330.9	657.6	27.4	132.8
1933:					
January	33.2	331.0	661.9	27.6	120.3
February	27.2	322.3	653.3	27.2	100.0
March	25.6	314.4	636.7	26.5	96.6
April	25.0	307.0	621.4	25.9	96.5
May	25.9	297.5	604.5	25.2	102.8

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Butterfat Feed Price Ratios, United States, by Months

(Continued)

Year and Month	Price Ratio	12 Month Moving Total	24 Month Moving Total	12 Month Moving Average Centered	Actual 12 Month Moving Average
1933 (*Cont.*)					
June	23.7	280.0	577.5	24.1	98.3
July	20.4	263.2	543.2	22.6	90.3
August	17.4	257.6	520.8	21.7	80.2
September	19.2	254.8	512.4	21.4	89.7
October	21.8	250.4	505.2	21.0	103.8
November	21.7	245.4	495.8	20.7	104.8
December	18.9	241.2	486.6	20.3	93.1
1934:					
January	16.4	239.1	480.3	20.0	82.0
February	21.6	239.2	478.3	19.9	108.5
March	22.8	236.1	475.3	19.8	115.2
April	20.6	230.4	466.5	19.4	106.2
May	20.9	226.2	456.6	19.0	110.0
June	19.5	224.4	450.6	18.8	103.7
July	18.3	226.0	450.4	18.8	97.3
August	17.5	225.9	451.9	18.8	93.1
September	16.1	222.1	448.0	18.7	86.1
October	16.1	222.1	444.2	18.5	87.0
November	17.5	218.4	440.5	18.4	95.1
December	17.1	215.1	433.5	18.1	94.5
1935:					
January	18.0	214.0	429.1	17.9	100.6
February	21.5	215.7	429.7	17.9	120.1
March	19.0	221.6	437.3	18.2	104.4
April	20.6	228.6	450.2	18.8	109.6
May	17.2	238.3	466.9	19.5	88.2
June	16.2	251.5	489.8	20.4	79.4
July	17.2	264.2	515.7	21.5	80.0
August	19.2	274.4	538.6	22.4	85.7
September	22.0	284.2	558.6	23.3	94.4
October	23.1	292.2	576.4	24.0	96.2
November	27.2	299.9	592.1	24.7	110.1
December	30.3	309.3	609.2	25.4	119.3
1936:					
January	30.7	315.6	624.9	26.0	118.1
February	31.7	318.0	633.6	26.4	120.1
March	28.8	317.3	635.3	26.5	108.7
April	28.6	314.5	631.8	26.3	108.7
May	24.9	307.0	621.5	25.9	96.1
June	25.6	295.6	602.6	25.1	102.0
July	23.5	283.2	578.8	24.1	97.5
August	21.6	269.3	552.5	23.0	93.9
September	21.3	259.0	528.3	22.0	96.8
October	20.3	247.1	506.1	21.1	96.2
November	19.7	238.3	485.4	20.2	97.5
December	18.9	229.4	467.7	19.5	96.9
1937:					
January	18.3	223.9	453.3	18.9	96.8
February	17.8	224.2	448.1	18.7	95.2
March	18.5	228.2	452.4	18.8	98.4
April	16.7	236.7	464.9	19.4	86.1

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Butterfat Feed Price Ratios, United States, by Months

(Continued)

Year and Month	Price Ratio	12 Month Moving Total	24 Month Moving Total	12 Month Moving Average Centered	Actual 12 Month Moving Average
1937 (*Cont.*)					
May	16.1	247.7	484.4	20.2	79.7
June	16.7	261.3	509.0	21.2	78.8
July	18.0	270.9	532.2	22.2	81.1
August	21.9	278.1	549.0	22.9	95.6
September	25.3	284.6	562.7	23.4	108.1
October	28.8	291.4	576.0	24.0	120.0
November	30.7	297.9	589.3	24.6	124.8
December	32.5	303.6	601.5	25.1	129.5
1938:					
January	27.9	309.3	612.9	25.5	109.4
February	25.0	312.5	621.8	25.9	96.5
March	25.0	312.6	625.1	26.0	96.2
April	23.5	310.0	622.6	25.9	90.7
May	22.6	306.5	616.5	25.7	87.9
June	22.4	301.6	608.1	25.3	88.5
July	23.7	298.2	599.8	25.0	94.8
August	25.1	297.4	595.6	24.8	101.2
September	25.4	294.2	591.2	24.6	103.3
October	26.2	290.7	584.9	24.4	107.4
November	27.2	287.8	578.5	24.1	112.9
December	27.6	285.8	573.6	23.9	115.5
1939:					
January	24.5	283.9	569.7	23.7	103.4
February	24.2	281.7	565.6	23.6	102.5
March	21.8	277.6	559.3	23.3	93.6
April	20.0	276.1	553.7	23.1	86.6
May	19.7	274.0	550.1	22.9	86.0
June	20.4	270.6	544.6	22.7	89.9
July	21.8	270.7	541.3	22.6	96.5
August	22.9	270.1	540.8	22.5	101.8
September	21.3	270.6	540.7	22.5	94.7
October	24.7	271.9	542.5	22.6	109.3
November	25.1	273.1	545.0	22.7	110.6
December	24.2	273.5	546.6	22.8	106.1
1940:					
January	24.6	274.4	547.9	22.8	107.9
February	23.6	275.8	550.2	22.9	103.1
March	22.3	279.4	555.2	23.1	96.5
April	21.3	281.1	560.5	23.4	91.0
May	20.9	283.0	564.1	23.5	88.9
June	20.8	288.0	571.0	23.8	87.4
July	22.7	289.1	577.1	24.0	94.6
August	24.3	290.9	580.0	24.2	100.4
September	24.9	294.2	585.1	24.4	102.0
October	26.4	299.2	593.4	24.7	106.9
November	27.0	306.1	605.3	25.2	107.1
December	29.2	313.4	619.5	25.8	113.2
1941:					
January	25.7	318.9	632.3	26.3	97.7
February	25.4	321.3	640.2	26.7	95.1
March	25.6	322.6	643.9	26.8	95.5

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Butterfat Feed Price Ratios, United States, by Months

(*Continued*)

Year and Month	Price Ratio	12 Month Moving Total	24 Month Moving Total	12 Month Moving Average Centered	Actual 12 Month Moving Average
1941 (*Cont.*)					
April	26.3	322.6	645.2	26.9	97.8
May	27.8	322.0	644.6	26.9	103.3
June	28.1	317.3	639.3	26.6	105.6
July	28.2	314.6	631.9	26.3	107.2
August	26.7	311.0	625.6	26.1	102.3
September	26.2	306.8	617.8	25.7	101.9
October	26.4	302.4	609.2	25.4	103.9
November	26.4	297.3	599.7	25.0	105.6
December	24.5	291.3	588.6	24.5	100.0
1942:					
January	23.0	285.4	576.7	24.0	95.8
February	21.8	283.2	568.6	23.7	92.0
March	21.4	283.0	566.2	23.6	90.7
April	21.9	285.0	568.0	23.7	92.4
May	22.7	287.7	572.7	23.9	95.0
June	22.1	292.5	580.2	24.2	91.3
July	22.3	297.1	589.6	24.6	90.7
August	24.5	302.8	599.9	25.0	98.0
September	26.0	308.0	610.8	25.5	102.0
October	28.4	312.0	620.0	25.8	110.1
November	29.1	314.2	626.2	26.1	111.5
December	29.3	315.8	630.0	26.3	111.4
1943:					
January	27.6	316.7	632.5	26.4	104.5
February	27.5	314.8	631.5	26.3	104.6
March	26.6	311.3	626.1	26.1	101.9
April	25.9	307.5	618.8	25.8	100.4
May	24.9	302.8	610.3	25.4	98.0
June	23.7	297.3	600.1	25.0	94.8
July	23.2	293.6	590.9	24.6	94.3
August	22.6	289.7	583.3	24.3	93.0
September	22.5	287.9	577.6	24.1	93.4
October	24.6	286.6	574.5	23.9	102.9
November	24.4	284.8	571.4	23.8	102.5
December	23.8	284.1	568.9	23.7	100.4
1944:					
January	23.9	284.1	568.2	23.7	100.8
February	23.6	284.7	568.8	23.7	99.6
March	24.8	287.9	572.6	23.9	103.8
April	24.6	289.3	577.2	24.1	102.1
May	23.1	291.3	580.6	24.2	95.5
June	23.0	293.8	585.1	24.4	94.3
July	23.2	296.1	589.9	24.6	94.3
August	23.2	298.9	595.0	24.8	93.5
September	25.7	300.3	599.2	25.0	102.8
October	26.0	304.9	605.2	25.2	103.2
November	26.4	307.9	612.8	25.5	103.5
December	26.3	311.1	619.0	25.8	101.9
1945:					
January	26.2	315.4	626.5	26.1	100.4
February	26.4	319.5	634.9	26.5	99.6

Table continued on next page.

Butterfat Feed Price Ratios, United States, by Months

(Continued)

Year and Month	Price Ratio	12 Month Moving Total	24 Month Moving Total	12 Month Moving Average Centered	Actual 12 Month Moving Average
1945 (*Cont.*)					
March	26.2	321.7	641.2	26.7	98.1
April	29.2	324.8	646.5	26.9	108.6
May	26.1	327.5	652.3	27.2	96.0
June	26.2	330.2	657.5	27.4	95.6
July	27.5	333.1	663.3	27.6	99.6
August	27.3	335.2	668.3	27.8	98.2
September	27.9	337.4	672.6	28.0	99.6
October	29.1	336.1	673.5	28.1	103.6
November	29.1	334.2	670.3	27.9	104.3
December	29.0	331.7	665.9	27.7	104.7
1946:					
January	29.1	325.9	657.6	27.4	106.2
February	28.5	321.3	647.2	27.0	105.6
March	28.4	319.1	640.4	26.7	106.4
April	27.9	320.4	639.5	26.6	104.9
May	24.2	320.0	640.4	26.7	90.6
June	23.7	321.5	641.5	26.7	88.8
July	21.7	319.5	641.0	26.7	81.3
August	22.7	315.6	635.1	26.5	85.7
September	25.7	311.5	627.1	26.1	98.5
October	30.4	306.0	617.5	25.7	118.3
November	28.7	302.6	608.6	25.4	113.0
December	30.5	298.5	601.1	25.0	122.0
1947:					
January	27.1	297.4	595.9	24.8	109.3
February	24.6	295.2	592.6	24.7	99.6
March	24.3	291.3	586.5	24.4	99.6
April	22.4	280.3	571.6	23.9	93.7
May	20.8	271.9	552.2	23.0	90.4
June	19.6	262.8	534.7	22.3	87.9
July	20.6	255.8	518.6	21.6	95.4
August	20.5				
September	21.8				
October	19.4				
November	20.3				
December	21.4				
1948:					
January	20.1				

QUESTIONS

Chapter 1

1. When were dairy products probably first used? For what purposes?
2. Name some of the sources of information about early dairying in Mesopotamia; Egypt; India; Switzerland.
3. How do some of the ancient dairy practices compare with modern practices?
4. Contrast dairying in old Rome and old Greece.
5. For what was butter used in early times?
6. Describe dairying in Europe at the beginning of the Christian era.
7. Where was butter first used extensively?
8. When did the increased use of butter begin? What was the cause?
9. Describe dairying at the beginning of the nineteenth century.
10. What major changes have taken place in dairy practices since 1900?
11. What are the 9 chief factors responsible for the major changes that have taken place?
12. In what ways have each of the 9 factors affected dairying?

Chapter 2

1. Why does a farmer have greater confidence that he is making a safe investment when he builds and equips a dairy barn than when he builds a packing shed for apples, or a house for raising broiler chickens?
2. If the price received for milk declines for a year or two, what is the probable explanation?
3. A business cycle consists of four stages: (1) revival, (2) boom, (3) recession, (4) depression. During which of these stages does the farmer find dairying most satisfactory from a price standpoint? Why?
4. In what part of the United States would you expect to find the lowest average milk production per cow? Why?
5. Why can we regard the opportunities for obtaining higher production of milk per cow from genetic improvement favorable in the future?
6. Does it pay an ordinary dairy farmer who depends upon his milk checks for an income to feed a cow for a production record that exceeds 20,000 pounds a year?
7. Why do we find dairy cows holding an important place in agriculture in every part of our country?

8. Name the five leading milk-producing states.
9. What state has the third largest number of cows but ranks only tenth in milk production? How can you account for this?
10. Why is dairying considered a good side-line enterprise for fruit growers, grain farmers or hog raisers?
11. Under what conditions and in what parts of the country are we most likely to find dairying the main enterprise of the farm?
12. About what proportion of the farm income in the United States is derived from dairying? What state gets 60 per cent of its agricultural income from dairying?
13. Describe the characteristic seasonal change in milk production. Where would you expect to find the least seasonal variation in production? Why?
14. Account for the tendency for higher milk-production costs in the North Atlantic states than in the North Central states.
15. List several reasons for the improved quality of milk that makes it a safe food for consumers.

Chapter 3

1. List the ways that farmers dispose of their milk. Indicate the factors a farmer takes into account when he decides what to do with his milk.
2. Who decides what is to be done with the 80 per cent of the milk which is delivered to market by farmers? What factors influence these decisions?
3. Arrange the following uses for milk in the order of their importance: (1) consumed as milk or cream, (2) used for making cheese, (3) used for making evaporated milk, (4) used for making creamery butter, (6) fed to calves.
4. What is the principal distinction between the chief products and the by-products made from milk?
5. How do you account for the relative unimportance of our foreign trade in dairy products?
6. How many pounds of milk are needed on the average to make a pound of butter? A pound of Cheddar cheese? A pound of evaporated milk?
7. About how much milk does the average person in the United States consume in a year in the form of fluid milk and cream? In all forms?
8. Is fluid consumption of milk and cream taking more or less of our total milk production than it did ten years ago? Is butter taking more or less than ten years ago?
9. Is butter consumption higher among low-income families or high-income families? Is it higher in good times or bad times from the standpoint of business conditions?
10. How do you account for the higher per capita consumption of cheese that has developed over the last 20 years?

11. Explain why evaporated milk tends to have a higher consumption in the South and among low-income families.
12. How many products can you name that use milk as a raw material?

Chapter 4

1. What is a market milkshed? What determines its size?
2. What is meant by surplus milk?
3. Why is market-milk production subjected to city milk ordinances and other sanitary regulations? Why are they frequently classified as trade barriers?
4. Where and under what conditions do we find rail transportation used to get fluid milk to market?
5. What functions do country milk stations serve?
6. Explain why a producer-distributor has a more complicated marketing problem than a farmer who sells his milk through a co-operative bargaining association.
7. Why do farmers form co-operative agencies to handle their milk-marketing problems?
8. Differentiate between the principal types of co-operative milk-marketing associations.
9. Cite the problems confronted by a milk-marketing co-operative association when it attempts to devise an equitable-payment plan.
10. What factors does a dealer have to take into consideration when he determines the flat price that he will pay for milk?
11. Why does a farmer object when market-milk dealers buy his milk only in certain seasons of the year?
12. How do you account for the fact that the farmer usually receives less than 50 per cent of the price of a quart of milk that is delivered to the home of a consumer?
13. What is meant by a class-price system of milk payment?
14. How is a market-wide price pool operated?
15. Outline the base-rating system of milk payment as it was originally planned. Point out some of the deviations from this original plan that have been made.
16. Trace the milk from the farm to the consumer in the form of market milk, taking at least five different courses that are used today.
17. What is the alternative to price competition that the milk dealers on most markets take?
18. Identify three distinct groups who have different economic interests but who are all concerned with the marketing of milk.
19. Is a store price differential on the retail price of market milk justified?
20. Why is the farmer "squeezed" the hardest when the price of milk slumps?

Chapter 5

1. What inventions made the rapid development of creamery butter making possible?
2. In what part of the United States is most of the creamery butter made?
3. Give the advantages and disadvantages of local and centralizer creameries.
4. How do you account for the large number of co-operative creameries? How do they differ from other creameries?
5. Most creameries report an overrun of more than 22 per cent. Can you explain how this is possible?
6. A group of creamery patrons are dissatisfied with the butterfat prices they are receiving. What could they do to better these prices?
7. When a chain store buys butter from a creamery and sells the butter through its own organization what market functions does it perform?
8. How do the large packing companies, such as Swift's and Armour's, obtain the butter they sell? How do they distribute it?
9. What services does a co-operative butter marketing association have to offer a creamery?
10. If a butter dealer buys butter at 28 cents a pound in May and sells it for 30 cents a pound in January does he make a net profit of two cents a pound?
11. Why is the butter price often called the basic price for the dairy industry?
12. Where are the principal butter exchanges located? How does a market reporter ascertain the price of butter?

Chapter 6

1. Describe the general location of the cheese industry. How is it changing?
2. What has caused the general trend toward larger cheese factories?
3. If you wanted to be a cheese maker would you hire out as an apprentice in a cheese factory or would you go to a dairy school?
4. How is cheese marketed by the factories?
5. What marketing advantages do cheese factories in Wisconsin have?
6. How has the introduction of process cheeses influenced the merchandising of cheese?
7. Why does packaged process cheese answer the needs of the modern housewife better than natural cheese?

Chapter 7

1. For what purposes are concentrated milk products made?
2. Explain the difference between condensed and evaporated milks.
3. Wisconsin is the outstanding state in the production of both cheese and evaporated milk. How do you explain this?

4. What is the relationship between ownership and the size of plants in the evaporated milk industry?
5. Where would an evaporated milk plant best fit into the picture of milk production zones? Why?
6. Why do milk evaporators pay more for their milk than whole milk creameries?
7. Why was the production of evaporated milk and cheese expanded greatly during the war?

Chapter 8

1. If you wanted to establish an ice cream plant, where would you try to locate it in relation to a town?
2. In what respects does the ice cream industry tend to stabilize the price of milk in the market milksheds?
3. What are the principal changes that have taken place in ice cream merchandising?
4. Although the production of ice cream is highly seasonal, the seasonal price changes are not great. How do you account for this?
5. How does an ice cream dealer attempt to escape the high maintenance costs which he encounters when his plant is operating below normal capacity?
6. What are the reasons for large fluctuations in the production of ice cream?

Chapter 9

1. List as many processes as you can think of that are used to convert milk into less perishable products.
2. What are the principal differences between the dried milk used for human consumption and that used for animal feeding?
3. Why do not city milk dealers operate dry milk plants along with their regular processing plants?
4. What are the principal outlets for skim milk? Rank them according to their importance.
5. Of what value is skim milk and buttermilk in animal feeding?
6. How do you explain the fact that so much skim milk, buttermilk, and whey are thrown away?
7. Why may we expect larger quantities of nonfat dry milk solids to be available on the market than was available prior to the last war?
8. Where do condensed skim milk products find their greatest use?
9. Name five industrial products in which casein is used as a raw material.
10. What milk by-product played an important part in the production of penicillin?

Chapter 10

1. How is information about the origin and early development of cattle obtained?
2. Describe the family *Bovidæ*.
3. Describe the subgenera of genus *Bos*.
4. From what subgenus of *Bos* are domesticated cattle descended?
5. Into what divisions and subdivisions is the subgenus *taurine* divided?
6. When were cattle probably first domesticated?
7. What is the probable origin of breeds?
8. Classify the modern breeds of cattle according to origin.
9. Classify the breeds according to use.
10. Classify cattle according to the degree of purity.

Chapter 11

1. Discuss the size, color, and type of Holstein.
2. How do Holsteins rank for disposition, maturity, and reproduction?
3. What are the chief characteristics of Holstein milk?
4. How do Holsteins rank for meat and veal production?
5. Describe the conditions of keeping cattle in Holland.
6. How has environment influenced the characteristics of the breed?
7. In what countries and regions are Holsteins most numerous?
8. Discuss families in the Holstein breed.
9. How are the records of purebred Holsteins kept?
10. Describe the Advanced Registry system.
11. Describe the Herd Classification system.
12. How does type correlate with production?

Chapter 12

1. Describe the size, color, and type of Jerseys.
2. How do Jerseys rank for nervous temperament, grazing ability, and reproduction?
3. How do Jerseys rank for age when mature? Meat and veal production?
4. What are the chief characteristics of Jersey milk?
5. For what is Jersey milk best adapted?
6. Describe the conditions of keeping cattle on the Island of Jersey.
7. How have the early environmental factors influenced the character of the Jersey?
8. Discuss the importations of Jerseys to the United States.
9. What functions do the American Jersey Cattle Club perform?
10. Describe the system of testing sponsored by the American Jersey Cattle Club.
11. What awards may Jersey cattle win?
12. Describe Herd Classification.

13. What is the relation between production and type as revealed by Herd Classification records?

Chapter 13

1. Describe the color, size, and general type of Guernseys.
2. Discuss the adaptability of the Guernsey.
3. How do Guernseys rank in maturity? Reproduction? For meat and veal?
4. What are the outstanding characteristics of Guernsey milk?
5. For what is Guernsey milk especially adapted?
6. Where did the Guernsey originate? From what stock?
7. When did importation of Guernseys begin?
8. What states have the most Guernseys?
9. Discuss the popularity of the Guernseys.
10. What services does the American Guernsey Cattle Club perform?
11. How does the Guernsey Cattle Club designate the type of record?
12. What different kinds of records are accepted for the Guernsey Advanced Register?
13. How does the Guernsey Herd classification scheme differ from the Jersey system?

Chapter 14

1. Describe the size and general type of the Ayrshire.
2. How do Ayrshires rank in disposition and as grazers?
3. At what age do Ayrshires mature?
4. How do Ayrshires rank for meat and veal production?
5. Describe Ayrshire milk. For what is it especially adapted?
6. From what stock did the Ayrshire probably originate?
7. Describe the condition under which the Ayrshire was developed.
8. How did this influence the characteristics of the Ayrshire?
9. Where are Ayrshires most numerous?
10. What services does the American Ayrshire Breeders Association render?
11. What types of records may Ayrshire breeders make?
12. What type of testing does the Ayrshire Association stress?
13. How do Official Test records of the Ayrshires compare with those of other breeds?

Chapter 15

1. Describe the general type of the Brown Swiss.
2. Describe the disposition of the Brown Swiss.
3. How do the Brown Swiss rank for age of maturity? As reproducers? For veal and meat?
4. Give the chief characteristics of Brown Swiss milk and its special adaptations.

5. Where, when, and from what stock did the Brown Swiss originate?
6. Describe the conditions in the native home of the Brown Swiss and the influences of these conditions upon the development of the cattle.
7. How many have been imported?
8. How do the Brown Swiss rank as high producers?
9. Describe the testing and herd classification systems.

Chapter 16

1. How are Milking Shorthorns differentiated from beef Shorthorns?
2. Describe the dairy characteristics and milk.
3. Rank Milking Shorthorns for (1) beef production, (2) veal production, and (3) grazing.
4. Describe the work and accomplishments of the great English Shorthorn breeders.
5. To what conditions are the Milking Shorthorns best adapted?
6. Describe the Advanced Registry system of the Milking Shorthorn.
7. How may one "grade up" Milking Shorthorns?

Chapter 17

1. Describe the size, color, and type of the Red Polled.
2. How do the Red Polled rank in temperament? Age of maturity?
3. How are the Red Polled qualified for veal and beef production?
4. Describe the Red Polled as milk producers.
5. Discuss the origin and development of the breed.
6. To what conditions are they best adapted?

Chapter 18

1. Describe the Dutch Belted.
2. Where and how were they developed?
3. Describe the importations to the United States.
4. Describe the Dutch Belted milk.
5. What is the origin of the French-Canadian breed?
6. Describe the French-Canadian.
7. Describe the milk of the French-Canadian.
8. Compare the Dexter and the Kerry.
9. Describe the Danish Red breed.
10. How is this new breed being developed?

Chapter 19

1. Classify dairy farms on the basis of intensity.
2. Describe the different types of dairy farms on the basis of the type of cattle kept.
3. How does the market outlet influence the type of dairying practiced?
4. What is the relative importance of choice of the individual animal and of breed in starting a dairy herd?

5. To what extent should the following govern the choice of a breed:
   a. Personal preference?
   b. The prevailing breed in a community?
   c. The market?
   d. Climate?
   e. Type of land?
   f. Demand for surplus stock?
6. How do breeds rank for:
   a. Efficiency of digestion?
   b. Maintenance requirements?
   c. Utilization of roughage?
   d. Vigor of calves?
   e. Early maturity?
   f. Veal production?
   g. Beef production?

Chapter 20

1. Why is the selection of individual cows important?
2. Compare the relative reliability of production records and appearance in selecting cows.
3. What animals can be safely eliminated by appearance?
4. What factors influence the reliability of production records?
5. Why should a student of dairying be familiar with dairy type?
6. Into what five divisions may the score card be divided?
7. How much reliance can be placed upon dairy conformation in selecting cows for production?
8. What anatomical features indicate strong constitution and vigor?
9. How is feed capacity indicated?
10. Describe the desirable udder.
11. What are the more common udder defects?
12. What is meant by style and general appearance? What is the relationship to production?

Chapter 21

1. Describe the body cell.
2. Why are the chromosomes important?
3. Describe oögenesis.
4. Describe spermatogenesis.
5. What is meant by Mendelism?
6. What is meant by the following terms: dominance; recessiveness; epistasis; cumulative inheritance?
7. In what ways does the modern concept of inheritance differ from that of Mendel?
8. What is meant by homozygous and heterozygous?
9. Of what importance is variation in inheritance?
10. What is genotype? Phenotype?
11. What is a hybrid?
12. What is meant by linkage?
13. Are acquired characters transmitted to the offspring?
14. What are mutations?

Chapter 22

1. Explain how an individual may have a poorer inheritance than either of its parents.
2. Why is the production record of the dam not a reliable index of the inheritance of her son?
3. What is meant by regression?
4. Why may crosses of distantly related parents not be good tests for genetic makeup?
5. What is the most effective cross for testing genetic makeup?
6. What are the limitations of genetic analysis of dairy cattle?
7. What is a pedigree?
8. Under what conditions may a pedigree be a valuable instrument in evaluating a dairy animal?
9. What is meant by "bull index"?
10. Of what value are bull indexes?

Chapter 23

1. Name four types of color inheritance.
2. How are the variations in shades of color of Jerseys and Ayrshires accounted for?
3. What are the allelomorphs of self?
4. Name five cases where white is dominant.
5. How is the black nose of the Guernseys inherited?
6. What lethal factors are known in cattle?
7. What is a freemartin?
8. What is the probable nature of the inheritance of the following:
   a. Milk production?
   b. Fat percentage?
   c. Persistency?
   d. Size?
   e. Vigor?
   f. "Type"?

Chapter 24

1. What are the advantages and disadvantages of crossbreeding?
2. What is the explanation for the improvement observed in outcrossing?
3. What is the essential difference between linebreeding and inbreeding?
4. What are the objectives of inbreeding?
5. What are the dangers of inbreeding?
6. When should inbreeding be practiced?
7. What is meant by "grading up"?
8. What methods did the old English breeders use?
9. What has genetics contributed to assist the breeder of dairy cattle?

Chapter 25

1. Why is the selection of a herd sire important?
2. To what extent should type be considered in selecting a herd sire?

3. How may the pedigree help in evaluating a bull?
4. What is a proven sire?
5. What are some of the objections to a proven sire?
6. What is a Bull Association? Give its advantages and disadvantages.
7. What are the essential features of a good house and yard for a bull?
8. What are the important features in correct handling of the bull?
9. What is the importance of exercise? How may a bull be exercised?
10. What is the relationship of the age of a bull and the quality of his offspring?
11. What are the causes of sterility? What are the remedies?

Chapter 26

1. When was artificial insemination first practiced?
2. When was the first artificial insemination society organized in U. S. A.?
3. What are the advantages of A. I.?
4. Name the disadvantages.
5. Describe the reproductive tract of the bull.
6. Describe the reproductive tract of the cow.
7. Describe methods of obtaining semen.
8. What are the main problems in caring for semen?
9. How may semen be diluted?
10. What tests may be applied to semen.
11. Describe the different types of artificial insemination societies.
12. Compare conception rates from natural and artificial breeding.

Chapter 27

1. What is a "purebred?"
2. What is its real purpose?
3. What have the purebreds contributed to dairy development?
4. Compare purebreds and grades as producers.
5. What is there in the breeding of purebred dairy cattle to interest competent breeders?
6. What qualifications must one possess to become a successful breeder of purebred cattle?
7. Why is it essential to test all purebreds?
8. What are public sales, and what do they accomplish?
9. In what different ways may a breeder advertise?
10. What systems may be used in naming purebred cattle?
11. What are the major business requisites for successful breeding?
12. What services should a breeder render beside selling purebreds?

Chapter 28

1. Why is the rate of growth important?
2. What are the growth periods?

3. How may growth be accounted for?
4. What is the effect of fattening upon cell size?
5. Discuss change of form in relation to growth.
6. What determines the limits of growth?
7. How does age affect the chemical composition of the body?
8. How is growth measured?
9. Of what value are normal growth figures?
10. What factors influence the birth weight of calves?
11. What factors influence the mature size of an animal?
12. What are the effects of gestation upon growth?
13. How does lactation affect growth?
14. What is the relationship between fatness of the growing heifer and the subsequent dairy type?
15. What is the relationship between rate of growth and sexual maturity?

Chapter 29

1. How many calves must be raised annually per 20 cows for replacement?
2. Discuss the selection of calves to be raised.
3. Compare the digestive tract of a calf with that of the mature animal.
4. Under what conditions are calves suffering from protein deficiencies?
5. What minerals may be inadequate in calves' rations?
6. What vitamin deficiencies may calves suffer from?
7. How long should a calf be left with the dam?
8. Of what importance is colostrum?
9. How should a calf be taught to drink out of a pail?
10. How much milk should be fed calves?
11. What are the dangers of overfeeding?
12. Describe changing the feed from whole milk to skim milk.
13. How do calves fed skim milk compare with those fed whole milk?
14. What supplement should be added when the calves are changed to skim milk?
15. Describe the problems encountered in raising calves where whole milk is sold.
16. Discuss the feeding of whey to calves.
17. How may buttermilk be used in raising calves?
18. How should dry milks be fed?
19. What kind of hay is best for calves?
20. Describe the difficulties encountered when whole milk alone is fed.
21. What effect upon calves has milk foam?
22. How is pasteurized milk as a calf food?
23. Discuss cleanliness as a factor in calf raising.
24. Describe a satisfactory calf pen.
25. Why is pasture not advised for calves receiving skim milk? Silage?
26. What are the relative merits of spring and fall calves?

27. How should a calf be weaned?
28. Discuss the economics of veal production.
29. What should be done to prevent calf diseases?
30. Give the causes, symptoms, and treatment of the following diseases:
    a. Common scours
    b. White scours
    c. Bloody scours
    d. Pneumonia
    e. Navel ill
    f. Goiter
    g. Ringworm
    h. Warts

Chapter 30

1. Why is rapid growth and development desirable?
2. Under what conditions may it pay to feed less than necessary for rapid growth?
3. What special problem is raised at weaning time?
4. How much and what kinds of concentrate should the 6-month to 12-month-old heifer have?
5. Discuss the relative merits of the different hays and silage.
6. How valuable is pasture for calves of this age?
7. What mineral supplements may be needed?
8. Discuss the winter feeding of yearling heifers with:
    a. Legume roughage
    b. Mixed hays
    c. Legumes and silage
    d. Grass hays and silage
9. What deficiencies are encountered when grain alone is fed?
10. Discuss the gains of heifers made on pasture when in poor condition and good condition.
11. Describe adequate housing for heifers.
12. What factors determine the age at which heifers should be bred?
13. What is the average and normal variations of the gestation period of cattle?
14. How much feed and labor are required to raise a heifer to 2 years of age?
15. Describe the feeding and care of a heifer before calving.

Chapter 31

1. Trace the evolution of the mammary glands.
2. Describe the division of the mammary glands of the cow.
3. Discuss the factors affecting the shape of the udder.
4. Describe the structure of the udder.
5. How does milk get into the gland cistern from the secretory tissue?
6. Describe the alveolus. A lobe.
7. How is blood supplied to the udder?
8. How does lymph leave the udder? What happens when lymph backs up in the udder?
9. How is the udder supplied with nerves?

10. Describe the embryological development of the udder.
11. How are the cisterns and ducts formed?
12. What causes the development of the ducts?
13. What causes the development of the alveoli?
14. What happens to the udder when lactation ceases?

Chapter 32

1. Into what four groups may the various theories of milk secretion be divided?
2. What are the objections to the theory of cell degeneration?
3. What hormones are involved in the secretion of milk?
4. What is the source of milk fat?
5. What evidence supports the contention that milk fat is synthesized independently of the other milk ingredients?
6. How may the shorter chain fatty acids of milk fat be accounted for?
7. What is the probable source of the milk proteins?
8. What is the blood precursor of milk sugar? How must it be changed to form milk sugar?
9. What are the sources of the mineral constituents of milk?
10. Discuss the ratio of the various salts of blood and milk.
11. What constituents of milk come unaltered from the blood?
12. When is milk secreted?
13. What is the relation between pressure and rate of milk secretion?
14. What happens to milk left in the udder?
15. What is the probable mechanism responsible for the "letting down" of milk?
16. What factors influence the "letting down" of milk?

Chapter 33

1. What general factors affect the composition and yields of milk?
2. What is meant by normal variation of milk?
3. How does the composition of milk vary with breeds?
4. Of what importance is persistency?
5. Discuss the effect of advancing lactation upon:
   a. Amount of milk
   b. Fat percentage
   c. Size of the fat globule
   d. Protein and other constituents
6. What causes bitter milk?
7. Compare colostrum with normal milk.
8. What is the effect of the number of milkings per day? How is the effect explained?
9. What is the effect of long and short intervals between milking upon yield and quality?
10. Discuss the difference in composition of fore and last drawn milk.
11. Do all quarters produce the same amount and quality of milk?

12. What is the effect of the order of milking the quarters upon yield and fat content?
13. How does the condition at calving influence the yield and composition of milk?
14. What is the relationship of the dry period to the yields of the following lactation period?
15. What is the difference in effect of the length of the dry period upon heifers and older cows? Explain.
16. When does gestation affect lactation?
17. Why does the milk yield decline with the advance in gestation?
18. What is the relationship for service period and average daily milk yields?
19. What is the effect of oestrum on milk production?
20. What is the effect of season on milk yield and fat percentage?
21. Explain why cows calving in the fall produce more milk than those calving in the spring.
22. What is the relationship of age to yield and fat percentage?
23. What is the relationship between the size of the cow and total production? Economy of production?
24. What is the effect of starvation upon the amount and composition of milk?
25. How may the fat percentage of milk be raised?
26. What is the effect of feed upon the composition of milk fat?
27. What vitamins of milk may be increased by feeding?
28. What is the difference between breeds in the use of carotene?
29. What mineral constituents may be increased or added to milk by feeding?
30. Name some drugs that may pass into the milk.
31. How are food flavors of milk accounted for?
32. How are food flavors eliminated from milk? State the principle.
33. Name some common weeds producing off flavors.
34. What are the effects of drugs upon milk yield?
35. What feeds may "dry off" cows?
36. How does disease affect milk?
37. Discuss the effect of digestive disturbances upon the composition and flavor of milk.

Chapter 34

1. What physiological functions have been studied for cows?
2. How does a cow become ruler of the herd?
3. Of what importance is regularity in management?
4. Of what importance is grooming? Exercise?
5. How should horns be removed, and what is the effect upon milk yield?
6. What are the more common vices that cows are addicted to? How may each be broken?

7. What is the normal gestation period of cows?
8. What is the normal oestrus cycle, and what factors influence it?
9. When should cows be bred for optimum results?
10. What is a normal breeding efficiency?
11. What factors are involved in sterility?
12. Why should a cow be given a rest period? How long?
13. What is the difference between cows and heifers in the length of rest period needed?
14. What are the main objectives in the care of the dry cow?
15. Describe the care and attention of a cow at calving time.
16. Describe the weights of cows during the dry period and following calving.
17. How should a cow be fed and cared for following calving?
18. What difficulties are frequently encountered following calving?
19. How should a case of retained afterbirth be treated?
20. How should a congested udder be treated?
21. What is the fundamental cause of milk fever? How should it be treated?
22. What precautions should be taken in "breaking in" a heifer to milking?
23. Should a cow be milked before calving? Why?
24. What is the cause of hard milking? How may such cases be treated?
25. Describe the relative merits of the different systems of drying-off cows.
26. How may leaky teats be treated? Sore teats? Warts?
27. When should a milk tube be used? How should it be cared for?
28. What effect has lengthening the interval between milking upon the amount and quality of the milk?
29. What are the reasons for cows leaving the herd?
30. What is the average productive life of a cow?
31. What damage do flies cause?
32. What are the more important flies attacking or annoying cattle?
33. How may flies be combatted?

Chapter 35

1. How much time is spent in milking a cow daily and for the year? What proportion is this of the total labor requirement?
2. Discuss the early development of milking machines.
3. Describe the stages in the development of suction milking machines.
4. Into what two classes do suction machines fall, and what are the essential differences?
5. How is intermittent vacuum obtained?
6. What is meant by a releasor system?
7. Describe the Roto-lactor.
8. How do hand and machine milking compare in efficiency?
9. Discuss stripping following milking by machine.

10. How does machine milking compare with hand milking for the quality of milk produced?
11. Under what conditions may milking machines be responsible for the spreading of udder diseases?
12. What factors decide whether a milking machine is economical?
13. What is the smallest herd for which a milking machine is economical?
14. What are the chief mistakes made in running a milking machine?
15. List the various steps necessary in cleaning the milking machine.
16. List the five rules for milking.
17. Describe the best milking routine in a barn.

Chapter 36

1. Why is the keeping of records important?
2. Give five methods of identifying animals and the relative merits of each.
3. What are the advantages of using herd numbers?
4. What is the relative value of milk records and fat percentage?
5. What are the merits of keeping daily milk weights?
6. What is the relative accuracy of determining fat percentage by testing one day each month?
7. How reliable is the use of the fat percentage for one lactation when applied to another lactation?
8. Describe a permanent herd book.
9. By what different agencies may testing be performed?
10. What are two objections to private record keeping?
11. Describe a Cow Testing Association.
12. What are the chief merits of a Cow Testing Association?
13. What are the chief merits of Official Testing? Objections to?
14. What is the Herd Test?

Chapter 37

1. What factors must be considered in determining the cost of producing milk?
2. Convert 5,000 pounds of milk testing 5 per cent into 4 per cent (F.C.M.). Also 5,000 pounds of 3 per cent milk.
3. What factors affect the coefficient of efficiency?
4. What is the relationship between C.E. and the cost of producing milk?
5. Discuss the relationship between increased production and feed costs, including the law of diminishing returns.
6. What factors affect the labor requirements for milk production? What proportion of the total cost is for labor?
7. What are the variations in charges for buildings?
8. Discuss charges for equipment.
9. What factors affect charges for depreciation of cattle?

10. What is included in miscellaneous costs, and how much do these amount to?
11. What credits besides sales of milk and butterfat should be made?
12. Discuss the "cost of milk production formulas."
13. What are the seasonal effects upon cost of milk production?

Chapter 38

1. How extensive is the loss from disease in dairy cattle?
2. Name the chief factors involved in the prevention and control of disease.
3. What is the relationship between the state of nutrition and susceptibility to disease?
4. What should the medicine cabinet contain?
5. Describe drenching an animal.
6. What are the symptoms of Bang's disease? Effects?
7. How should a herd be handled when infected with Bang's disease?
8. How is tuberculosis detected and controlled?
9. Describe John's disease and its treatment.
10. Describe hemorrhagic septicemia and its treatment and control.
11. What is trichomonad disease, and how may it be controlled?
12. Describe actinomycosis, its treatment and control.
13. Describe pink eye, its treatment and control.
14. How may footrot be controlled?
15. What is cowpox? How should cases of this disease be handled?
16. What causes bloat? How should it be treated?
17. What are the causes of mastitis?
18. How may mastitis be detected?
19. Discuss the merits of various treatments for mastitis.
20. What methods may prevent mastitis?

Chapter 39

1. Name five important considerations in planning a dairy barn.
2. Why is the warmth of a barn important?
3. What are the requirements in the barn for the production of clean milk?
4. Describe the requisites for the location of a barn.
5. What direction should the barn face?
6. How may barns be classified?
7. What are the advantages and disadvantages of the different types of barns?
8. What factors determine the type of building material to be used in the construction of a barn?

9. What must be known before the interior of a barn can be properly planned?
10. Discuss the relative advantages of facing cows in and facing them out.
11. Discuss the factors that determine the dimensions of a dairy barn.
12. What determines the size of stalls to be used?
13. Discuss the sizes and location of the different alleyways.
14. What are the advantages and disadvantages of the different types of barn floors?
15. What are the requisites of an ideal floor for the stall?
16. Describe the size and location of windows for a barn.
17. What are the purposes of ventilation?
18. What are the chief differences between the air before and after inhalation?
19. What are the problems encountered in attempting to ventilate a barn?
20. What are the advantages and disadvantages of the different systems of ventilation?
21. Discuss the different types of labor-saving devices used in feeding, and in cleaning the barn.
22. What is meant by loose housing? What are the advantages?
23. What is a milking parlor?
24. What are the advantages of the elevated milking stall?
25. What are the problems in training cows?

Chapter 40

1. What are the three most important elements concerned with soil fertility?
2. Discuss the variation between different crops in the amounts of fertility removed from the soil.
3. How may livestock production preserve soil fertility?
4. When may soil fertility be improved by the keeping of livestock?
5. What factors influence the composition of manure?
6. What is a year's production of manure from a cow worth?
7. Upon what factors does the annual amounts of manure from a cow depend?
8. How heavy may be the losses in manure, and what factors are responsible for these losses?
9. What are the qualifications of good bedding?
10. How much bedding is needed per cow per day?

Chapter 41

1. Why are cows generally undernourished?
2. For what is food used in the animal body?
3. What are the essential dietary substances?

4. What is meant by total digestible nutrients?
5. What is meant by net energy?
6. How are digestible nutrients determined? Net energy?
7. What are the losses of energy from the body?
8. In what forms may energy be stored in the body?
9. Of what importance is fat in the diet?
10. For what is protein used? Of what importance is the quality of the protein?
11. What minerals are needed for animal nutrition?
12. What are the functions of minerals in the body?
13. What are the common salt needs of cattle? How may salt be supplied?
14. What are the symptoms when phosphorus is deficient? Calcium?
15. In what ways may adequate phosphorus be supplied?
16. How may calcium deficiency be corrected?
17. What are the symptoms of iodine deficiency?
18. How may iodine deficiency be corrected?
19. Where may the iron and copper content of feeds be inadequate? What are the symptoms?
20. What are the symptoms of cobalt deficiency?
21. Under what conditions may there be a vitamin A deficiency? What are the symptoms?
22. How may vitamin A be preserved in feeds?
23. When is the vitamin A content of milk high?
24. Of what importance is vitamin B in dairy cattle feeding?
25. Of what importance is vitamin C?
26. What are the symptoms of vitamin D deficiency in cattle?
27. Which feeds are low and which are high in vitamin D?
28. Of what importance is vitamin E in dairy cattle feeding?
29. What is the relationship between the concentration in the feed and in the milk of each of the vitamins?
30. Describe the evolution of the feeding standards and give the specific contributions of each standard to better feeding.
31. Of what practical use is a feeding standard?
32. Balance a ration for a 1,200-pound cow producing 50 pounds of milk with 3.5 per cent fat content, using alfalfa hay, corn silage, corn, barley, and oats.
33. What are the uses of water in the body?
34. What determines the water needs of a cow?
35. What are the relative merits of the different ways of supplying water?
36. What are the chief considerations as to whether a ration is suitable?
37. What is the importance of balancing a ration?
38. Of what importance is palatability of the ration?
39. When may a ration be too bulky? Too heavy?
40. How essential is a consideration of succulence in the ration?

41. What is the fundamental reason for feeding concentrates? Explain.
42. What effects of feeds upon the milk and upon the system must be considered?
43. Discuss a number of plants that may poison cattle, and list other ways in which they may be poisoned.
44. Discuss the importance of the cost of the ration.

Chapter 42

1. Classify feeds into the different groups.
2. Discuss the importance of roughage in the ration.
3. Compare the value of alfalfa hay with other legumes and with other hays.
4. What are the chief nonlegume hays, and how do they compare in value with one another and with legumes?
5. Of what feed values are the fodders? What influences their feed values?
6. What is the feed value of stover? When should stover be used?
7. Compare the values of corn meal with corn and cob meal.
8. How do the sorghum grains rank as feed?
9. Discuss each of the cereal grains as feeds for dairy cattle.
10. Where are soybeans of special value?
11. What are the relative values of the various by-products of corn? Of wheat? Of oats?
12. Compare brewers' and distillers' grains as feeds.
13. Compare cottonseed meal with linseed oil meal as to their effect upon the animal and as a source of protein. With soybean oil meal.
14. What precaution should one take in buying screenings?
15. How do roots, tubers, and pumpkins rank as feeds?
16. What is the feed value of molasses, and what special uses are made of it?
17. What animal by-products may be used for feeding dairy cattle, and what difficulties are encountered in feeding them?
18. What is formed to preserve silage in the natural fermentation process?
19. Describe processes that are used for preserving green material.
20. What are the advantages of silage? Disadvantages?
21. What are the essential considerations for making good silage?
22. Describe the various kinds of silage.
23. Of what value are "digesting" processes?
24. Why should grains be ground?
25. Discuss the advisability of grinding roughages.
26. What are the pros and cons for chopping and shredding roughages?
27. Of what value is cooking or soaking grains?

Chapter 43

1. How may the problems incident to feeding dairy cows be divided into groups?

2. Show how liberal feeding is economical under normal conditions.
3. In what ways may concentrates improve the ration?
4. Discuss the merits of each of two sets of rules for feeding.
5. What different feeding problems are encountered when the roughage is of low, medium, and high protein content?
6. Under what conditions may it be economical to feed cows on limited amounts of concentrate?
7. What are the relative yields in nutrients for grains and roughages?
8. What are the relative costs of producing nutrients in grains and roughages?
9. What are the essentials for satisfactory returns when limited amounts of concentrates are fed?
10. Under what conditions is it desirable to feed cows for maximum production?
11. Describe the essentials of a ration for "test cows."

Chapter 44

1. What are the general problems in furnishing adequate pasture?
2. Compare young pasture grass with hay and concentrates.
3. How does increase in maturity affect the composition of grass? Of legumes?
4. How much grass will a cow consume?
5. What factors affect the amount of grass a cow will consume?
6. Discuss the relative yields of pasture and harvested crops.
7. What are the relative costs of nutrients from pasture and from harvested crops?
8. What are the effects of grazing upon pasture yield?
9. What are the most important considerations in the proper management of pastures?
10. In what ways may pastures be supplemented?
11. What governs the amount of concentrates a milking cow on pasture should be fed?
12. What are the most important pasture grasses for your section?
13. What are the advantages and disadvantages of legumes for pasture?
14. Discuss the crops best suited for supplementary pastures.
15. How may pasture be supplied when the regular pasture is destroyed?

Chapter 45

1. Define milk.
2. Describe the appearance and taste of milk.
3. What are the similarities and differences of the milks from different species?
4. What are the extreme variations in the composition of cows' milk?
5. Describe the composition of milk fat, and tell why it differs from other fats.

6. What other fatlike compounds are found in milk?
7. What causes variation in the chemical makeup of milk fat?
8. Classify the fatty acids.
9. What are the three proteins of milk?
10. Give the chief characteristics of each protein.
11. What are the other nitrogen compounds of milk?
12. Describe lactose.
13. What causes souring of milk?
14. What are the chief minerals of milk?
15. Describe each of the milk pigments.
16. Name and describe the enzymes of milk.

Chapter 46

1. Describe the general structure of milk.
2. What materials are in solution?
3. What constituents of milk are colloidal?
4. Describe the physical characteristics of fat in milk.
5. How does milk react chemically?
6. What factors affect the specific gravity of milk and cream?
7. What constituents of milk contribute to lowering its freezing point?
8. What practical uses are made of the freezing point and specific gravity of milk?
9. What factors influence the specific heat of milk and cream?
10. What influences the viscosity of milk and cream?
11. Describe the electrical conductivity and surface tension of milk.
12. What factors influence the creaming of milk?
13. How is foam formed?
14. What are the sizes and factors influencing the size of fat particles in milk?
15. Name the common physical and chemical constants of milk fat.
16. What are the effects of heating upon milk?
17. How does freezing alter milk and cream?
18. What does vigorous agitation do to milk? To cream?
19. Describe oxidation in milk, cream, and butter.
20. What are the effects of enzyme action on milk?

Chapter 47

1. Who were the leaders in the discovery and early development of bacteriology? Of dairy bacteriology?
2. What organisms are included in microbiology?
3. What are the morphologic and reproductive characteristics of each of the groups of microorganisms?
4. What are the sources of microorganisms in milk?

5. What are the most important precautions that must be taken to reduce the contamination of milk?
6. What are the requirements of microorganisms for growth?
7. Why is milk a good substrate for the growth of microorganisms?
8. How do bacteria differ in their requirements for growth?
9. What methods are used to determine the microorganisms of milk?
10. Name the changes brought about by microorganisms in milk.
11. The formation of what dairy products is dependent upon microorganisms?
12. Upon what action of the microorganisms is each of these products dependent?
13. What undesirable fermentations are produced? Describe each one.
14. What important disease producing organisms may be borne by milk?
15. How may harmful microorganisms be destroyed in milk?

Chapter 48

1. Describe the proper sampling of milk or cream.
2. How should a composite sample be taken?
3. What three preservatives may be used, and what are the relative merits of each?
4. Describe the procedure for conducting the Babcock test (a) for milk, (b) for skim milk, and (c) for cream.
5. What is the butyl alcohol test?
6. What are the causes of the following defects: Black particles in the fat column? Too-dark fat column? White or grayish particles in the fat? Bubbles on the surface of the fat?
7. How may each be prevented?
8. Describe the Minnesota Babcock test.
9. What are the principles of the Roese-Gottlieb test?
10. How may total solids of milk be determined?
11. How is the amount of casein determined?
12. Describe the determination of acidity.
13. Describe the determination of sediment by three different methods.
14. What is the principle of the brom-thymol-blue test?
15. What is the alcohol test, and what is its value?
16. What is the principle of the methylene blue test?
17. How may one determine whether or not milk has been heated?

Chapter 49

1. What is the effect of straining upon milk?
2. How thorough is the gravity creaming?
3. When and by whom was the centrifugal separator invented?
4. Describe the bowl of a separator.
5. What factors influence the fat content of cream?

6. What factors affect the efficiency of a separator?
7. What is separator slime?
8. What is the effect of separation on bacterial content of the cream, skim milk, and slime?
9. What is the relationship between temperatures and bacterial development?
10. What different methods may be used in cooling milk or cream?
11. What is the effect of clarification upon the composition and bacterial content of milk?
12. Describe the different methods of pasteurization.
13. What is the effect of pasteurization upon the physical properties of milk? Upon the chemical properties?
14. What is the principle of homogenization?

Chapter 50

1. What is meant by market milk?
2. What are the different kinds of market milk?
3. Of what importance is the health of the cows and the feeds fed?
4. Specify the essentials of a dairy barn to meet the demands for market milk production.
5. Describe the equipment necessary for the production of market milk.
6. Name the important steps in the production of clean milk.
7. Describe a method of cleaning and sterilizing milk equipment.
8. What is certified milk?
9. What are the problems in the transportation of milk? How are they met?
10. Trace milk through a modern milk plant.
11. What factors influence the delivery cost of milk?
12. How much each of 3.0 per cent and 4.2 per cent milk is needed to make a 3.5 per cent milk?
13. How much skim milk and 4.2 per cent milk is needed to make a 4.0 per cent milk?
14. How is the public insured of a safe and wholesome market milk?

Chapter 51

1. What are the constituents of butter?
2. What is meant by the "double standard"?
3. Describe the structure of butter.
4. What are the fundamental principles involved in churning?
5. Discuss the theories of churning.
6. Name all the steps in churning, from loading the churn to removing the butter, and discuss the importance of each.
7. What are the classes of butter on the basis of treatment? On the basis of source? On the basis of quality?

8. In scoring butter, what points are considered?
9. What are the requirements and the common defects for each under number 8?
10. What effect has temperature upon churning?
11. Name the other factors affecting churning, and describe the effect.
12. Discuss quality of cream in relation to butter making.
13. What four processes may cream for butter making be subjected to?
14. What is the object of each?
15. What are some of the common tests used in the process of butter making?

Chapter 52

1. Classify cheese on the basis of hardness.
2. Classify cheese on the basis of the product from which it is made.
3. What constituents of milk are used in cheese making?
4. How may the coagulum be formed?
5. How do rennin and pepsin act upon milk?
6. What are the chief variations in the composition of the different cheeses?
7. Why is high quality milk essential for cheese making?
8. What is the relationship between the fat content of the milk used and the yield of cheese?
9. Describe the preparation of the milk for setting.
10. Describe the process from the addition of the rennet to cutting the curd for Cheddar cheese making.
11. How is the cut curd packed for Cheddar cheese?
12. What are the important considerations in curing Cheddar cheese?
13. In what ways does the making of Swiss cheese differ from that of Cheddar cheese?
14. Describe the process for making brick cheese.
15. In what important details does the making of Roquefort cheese differ from that of Cheddar cheese?
16. What are the chief differences between rennet cheeses and cottage cheese?
17. Describe cheese, Neufchâtel, Camembert, and Limburger cheese.
18. What is Primost?
19. What are the by-products of cheese making?

Chapter 53

1. What are the reasons for condensing and drying milk?
2. Define condensed milk, evaporated milk, superheated milk, and semi-solid buttermilk.
3. What are the Federal standards for evaporated and condensed milks?
4. Why is sugar added to condensed milk?

5. Describe the general properties of condensed milks.
6. What are the chief factors involved in the keeping qualities of condensed milks?
7. What is the principle of condensing?
8. Describe the process of condensing.
9. Describe the different processes employed in drying milk.
10. What are the advantages of the spray process over the drum process?
11. Classify dried milks according to the process employed in their manufacture and according to the product.
12. Discuss the factors causing variations in the composition of dried milks.
13. Describe the physical properties of milk powders.
14. Compare reconstituted milks with natural milks.
15. Describe the chief deteriorations of milk powders due to aging.
16. What are the chief uses for dried milks?

Chapter 54

1. Define ice cream.
2. What are the important groups of constituents of ice cream?
3. How much fat and total solids should ice cream contain?
4. Describe ice cream from a physico-chemical standpoint.
5. What are the different classes of ice cream?
6. What steps must be taken in preparing an ice cream mix for freezing?
7. What are the effects upon an ice cream mix of homogenization and aging?
8. What are the important points in the proper freezing of ice cream?
9. What different methods are used in making commercial casein? Describe each briefly.
10. What factors affect the quality of casein?
11. How is lactose prepared from milk?
12. Name and briefly describe each of the fermented milks.

REFERENCE READINGS

Chapter 1

PIRTLE, T. R. History of Dairying. Chicago, 1926.

WINKLER, W. Handbuch der Milchwirtschaft, Vol. III. Vienna.

Chapter 2

ANONYMOUS. LIVESTOCK ON FARMS, JAN. 1. Crop Reporting Board. U. S. Dept. Agr., Washington, D. C. Press release, Feb. 16, 1949.

ANONYMOUS. AGRICULTURAL STATISTICS 1947. U. S. Dept. Agr., Washington, D. C. 1949.

ECKLES, C. H., COMBS, W. B., AND MACY, H. Milk and Milk Products. Third edition. McGraw-Hill Book Co., New York. 1947.

ELLIOTT, F. F. TYPES OF FARMING IN THE UNITED STATES. Bur. of Census, U. S. Dept. Commerce. 1933.

JENNINGS, R. D. UNITS OF LIVESTOCK PRODUCTION. U. S. Dept. Agr., Washington, D. C. F. M. 63, April 1948.

JENSEN, EINAR, ET AL. INPUT-OUTPUT RELATIONSHIPS IN MILK PRODUCTION. U. S. Dept. Agr. Technical Bulletin No. 815. 1942.

SHEPARD, JOHN B. AND SMITH, R. K. LARGE AND SMALL DAIRY HERDS. Statistical supplement No. 9 to Milk Production Trends. Div. of Crop and Livestock Estimates, U. S. Dept. Agr., Washington, D. C. 1934.

WILSON, JOHN L. AND TAYLOR, FRANK M. FARM PRODUCTION, DISPOSITION AND INCOME FROM MILK, 1947–48. U. S. Dept. Agr., Washington, D. C. April 1949.

WILSON, JOHN L. AND TAYLOR, FRANK M. RATIONS FED TO MILK COWS, 1948. U. S. Dept. Agr., Washington, D. C., Jan. 1949.

Chapter 3

ANONYMOUS. CONVERSION FACTORS AND WEIGHT MEASURES FOR AGRICULTURAL COMMODITIES AND THEIR PRODUCTS. U. S. Dept. Agr., Washington, D. C. Aug. 1947.

BARTLETT, R. W. PRICES AND CONSUMPTION OF MILK IN SPECIFIC CITIES. Ill. Agr. Expt. Sta. Bul. 397. 1934.

BORMUTH, W. D. PRODUCTION OF MANUFACTURED DAIRY PRODUCTS, 1947. U. S. Dept. Agr., Washington D. C. Dec. 1948.

FROKER, R. K. AND HARDIN, C. M. PAYING PRODUCERS FOR FATS AND SOLIDS-NOT-FAT IN MILK. Wis. Agr. Expt. Sta. Res. Bul. 143. 1942.

O'DONNELL, P. E. CONSUMPTION OF FLUID MILK AND CREAM IN NORTH-

EASTERN MARKETING AREAS. Bureau of Agricultural Economics, U. S. Dept. Agr., Washington, D. C. 1948.

WAITE, W. C. AND COX, R. W. A STUDY OF CONSUMPTION OF DAIRY PRODUCTS IN MINNEAPOLIS, 1934. Minn. Agr. Expt. Sta. Bul. 311. 1934.

Chapter 4

ADAMS, T. M., ET AL. A RECOMMENDED BASIS FOR PRICING CLASS I MILK IN THE BOSTON MARKET. A report by the Boston Milkshed Price Committee. Market Administrator, Federal Milk Marketing Order, Boston, Mass. Sept. 1947.

ANONYMOUS. AN ANALYSIS OF THE SPREAD BETWEEN FARM AND CONSUMER MILK PRICES IN NEW YORK CITY UNDER PRESENT PRACTICES. Annual Report of the New York State Temporary Commission on Agriculture 1948–49, Part I. March 1949.

BLACK, J. D. THE DAIRY INDUSTRY AND THE AAA. The Brookings Institution No. 64, Washington D. C. 1935.

BRESSLER, R. G., JR. ECONOMIES OF SCALE IN THE OPERATION OF COUNTRY MILK PLANTS. New England Research Council on Marketing and Food Supply. Boston, Mass. June 1942.

BRESSLER, R. G., JR., AND HAMMERBERG, D. O. EFFICIENCY OF MILK MARKETING IN CONNECTICUT: 3. Economics of the Assembly of Milk. Storrs Agr. Expt. Sta. Bul. 239. 1942.

DOW, G. F., ET AL. FACTORS AFFECTING SEASONAL MILK PRODUCTION AND THEIR EFFECT ON PRODUCERS' COSTS AND RETURNS. Maine Agr. Expt. Sta. Bul. 459. 1948.

GAUMNITZ, E. W. AND REED, O. M. SOME PROBLEMS INVOLVED IN ESTABLISHING MILK PRICES. U. S. Agr. Adjust. Adm., Div. of Mktg. and Mktg. Agreements Mktg. Inf. Series DM-2. 1937.

HAMMERBERG, D. O., PARKER, L. W., AND BRESSLER, R. G., JR. EFFICIENCY OF MILK MARKETING IN CONNECTICUT: 1. Supply and Price Relationships for Fluid Milk Markets. Storrs Agr. Expt. Sta. Bul. 237. 1942.

HAMMERBERG, D. O. AND SULLIVAN, W. G. EFFICIENCY OF MILK MARKETING IN CONNECTICUT: 2. The Transportation of Milk. Storrs Agr. Expt. Sta. Bul. 238. 1942.

HERRMANN, L. F. AND WELDEN, WM. C. DISTRIBUTION OF MILK BY FARMERS' CO-OPERATIVE ASSOCIATIONS. Farm Credit Administration Circ. C-124. 1941.

JESNESS, O. B., WAITE, W. C., AND QUINTUS, P. E. THE TWIN CITY MILK MARKET. Minn. Agr. Expt. Sta. Bul. 331. 1936.

LININGER, F. F. THE RELATION OF THE BASIC-SURPLUS MARKETING PLAN TO MILK PRODUCTION IN THE PHILADELPHIA MILKSHED. Pa. Agr. Expt. Sta. Bul. 231. 1928.

MORTENSON, W. P. ECONOMIC CONSIDERATIONS IN MARKETING FLUID MILK. Wis. Agr. Expt. Sta. Res. Bul. 125. 1934.

QUINTUS, PAUL E. CO-OPERATIVE CREAMERY TRUCK ROUTES IN THE UNITED STATES. Farm Credit Administration, U. S. Dept. Agr. Misc. Report 52. April 1942.

SONLEY, L. T. COST OF TRANSPORTING MILK AND CREAM TO BOSTON. Vt. Agr. Expt. Sta. Bul. 462. 1940.

SPENCER, LELAND. THE SURPLUS PROBLEM IN THE NORTHEASTERN MILK-SHEDS. Farm Credit Administration Bul. 24. 1938.

STITTS, T. G. AND GAUMNITZ, E. W. RELATIVE PRICES TO PRODUCERS UNDER SELECTED TYPES OF MILK POOLS. Farm Credit Administration Bul. 25. 1938.

STITTS, T. G. AND WELDEN, WM. C. ECONOMIC ANALYSIS OF BARGAINING PROBLEMS OF MILK CO-OPERATIVES. Farm Credit Adm. Circ. c-104. 1937.

VARNEY, H. R. TRANSPORTATION OF MILK AND CREAM TO THE NEW YORK MARKET. Cornell Agr. Expt. Sta. Bul. 655. 1936.

WHITTAKER, H. A., ET AL. MILK PRODUCTION AND CONTROL. Century Co., New York. 1932.

Chapter 5

COWDEN, J. M. AND TRELOGAN, HARRY C. FLEXIBILITY OF OPERATION IN DAIRY MANUFACTURING PLANTS. U. S. Dept. Agr. Circ. 799. 1948.

HOWE, C. B. MARKETING MARGINS AND COSTS FOR DAIRY PRODUCTS. U. S. Dept. Agr. Technical Bul. 936. 1946.

HUNZIKER, O. F. THE BUTTER INDUSTRY. Second edition. Published by the author, La Grange, Ill. 1927.

KOLLER, E. FRED AND JESNESS, O. B. ORGANIZATION AND OPERATION OF MINNESOTA CO-OPERATIVE CREAMERIES. Minn. Agr. Expt. Sta. Bul. 333. 1937.

NICHOLLS, W. H. POSTWAR DEVELOPMENTS IN THE MARKETING OF BUTTER. Iowa Agr. Expt. Sta. Res. Bul. 250. 1939.

ROBOTKA, F. AND LAUGHLIN, G. C. CO-OPERATIVE ORGANIZATION OF IOWA FARMERS' CREAMERIES. Iowa Agr. Expt. Sta. Bul. 14. 1937.

TRELOGAN, H. C. A REVIEW OF THE OLEOMARGARINE SITUATION. Jour. Farm Econ. 18:616–621. 1936.

Chapter 6

EBLING, WALTER H., ET AL. WISCONSIN DAIRYING. Wis. Crop and Livestock Reporting Service, Bul. 200. Madison, Wisconsin. April 1939.

HOBSON, A. AND SHAARS, M. A. CONSUMER PREFERENCES FOR CHEESE. Wis. Agr. Expt. Sta. Res. Bul. 128. 1935.

NICHOLLS, W. H. POSTWAR DEVELOPMENTS IN THE MARKETING OF CHEESE. Iowa Agr. Expt. Sta. Res. Bul. 261. 1939.

SOMMER, H. H. AND TEMPLETON, H. L. THE MAKING OF PROCESSED CHEESE. Wis. Agr. Expt. Sta. Res. Bul. 137. 1939.

Chapter 7

BAKER, B. A. AND FROKER, R. K. THE EVAPORATED MILK INDUSTRY UNDER FEDERAL MARKETING AGREEMENTS. Wis. Agr. Expt. Sta. Res. Bul. 156. 1945.

HUNZIKER, O. F. CONDENSED MILK AND MILK POWDER. Sixth edition. Published by the author, La Grange, Ill. 1946.

MARKETING AGREEMENT FOR EVAPORATED MILK. U. S. Govt. Printing Office, Washington, D. C. 1933.

SOME FACTS ABOUT EVAPORATED MILK AND OTHER DAIRY PRODUCTS. Evaporated Milk Association, Chicago. 1937.

Chapter 8

BOND, M. C. THE MARKETING OF MILK THRU ICE CREAM. Cornell University Agr. Expt. Sta. Bul. 546. 1932.

DAHLE, C. D., ET AL. ANALYSIS OF DELIVERY PRACTICES IN THE ICE CREAM INDUSTRY FOR THE YEAR 1945. International Association of Ice Cream Manufacturers Special Bul. 72. 1947.

Chapter 9

ANONYMOUS. PRODUCTION AND DISTRIBUTION OF WHEY IN WISCONSIN. Economic Information for Wisconsin Farmers. Sept.–Oct. 1948.

COOK, H. L. AND DAY, G. H. THE DRY MILK INDUSTRY. American Dry Milk Institute, Inc. Chicago. 1947.

FOELSCH, GERTRUDE G. AND TRELOGAN, HARRY C. MILK SUGAR. The Dairy Situation, pp. 15–18, Oct. 1946.

KOLLER, E. FRED. THE MINNESOTA DRY MILK INDUSTRY. Minn. Agr. Expt. Sta. Bul. 372. 1943.

MORTENSON, W. P. MARKET OUTLETS FOR DRY WHOLE MILK. Wis. Agr. Expt. Sta. Stencil Bul. 7. 1948.

SUTERMEISTER, E. CASEIN AND ITS INDUSTRIAL APPLICATIONS. The Chemical Catalogue Co. New York. 1927.

TRELOGAN, HARRY C. AND HYRE, FRENCH M. CO-OPERATIVE MARKETING OF DAIRY PRODUCTS. Farm Credit Administration Circular C-116. 1939.

Chapter 10

KELLER, CONRAD. Naturgeschichte der Haustiere. Zurich. 1902.

MORSE, E. W. THE ANCESTRY OF DOMESTICATED CATTLE. Separate. 27th Ann. Rept. Bur. An. Ind., U. S. Dept. Agr. 1910.

PRENTICE, E. P. American Dairy Cattle. Harper & Brothers, New York. 1942.

WERNER, HUGO. Die Rinderzucht. Berlin. 1902.

Chapter 11

PRESCOTT, M. S., PRICE, F. T., WING, H. H., AND PRESCOTT, W. A. HOLSTEIN-FRIESIAN HISTORY. Holstein-Friesian World, Lacona, N. Y. 1930.

THE HOLSTEIN-FRIESIAN WORLD. Lacona, N. Y.

WILSON, JAMES. The Evolution of British Cattle and the Fashioning of Breeds. London. 1909.

Literature is obtainable from the Holstein-Friesian Association of America, Brattleboro, Vt.

Chapter 12

GOW, R. M. The Jersey. American Jersey Cattle Club, New York.

Literature is obtainable from the American Jersey Cattle Club, Columbus, Ohio.

Chapter 13

CALDWELL, W. H. Langwater Guernseys. Rumford Press. 1925.

HILL, CHAS. L. GUERNSEY BREED. Kimball Dairy Farmer. Waterloo, Ia. 1917.

Literature is obtainable from the American Guernsey Cattle Club, Peterboro, N. H.

Chapter 14

Literature is obtainable from the Ayrshire Breeder's Association, Brandon, Vt.

Chapter 15

Literature is obtainable from the Brown Swiss Cattle Breeder's Association, Beloit, Wis.

Chapter 16

SANDERS, A. H. Shorthorn Cattle. Third edition. Sanders Pub. Co., Chicago. 1916.

Literature is obtainable from the American Milking Shorthorn Society, 4122 S. Union Ave., Chicago.

Chapter 17

Literature is obtainable from the Red Poll Cattle Club, Lincoln, Neb.

Chapter 19

BOSS, A. AND POND, G. A. Modern Farm Management. Webb Book Publishing Company, St. Paul, Minn. 1947.

COCHRANE, E. R. The Milch Cow in England. Faber and Faber Ltd., London. 1944.

FRASER, W. J. Dairy Farming. John Wiley and Sons, Inc., New York. 1930.

Chapter 20

ECKLES, C. H., ANTHONY, E. L. AND PALMER, L. S. Dairy Cattle and Milk Production. The Macmillan Co., New York. 1939.

FRASER, W. J. Dairy Farming. John Wiley and Sons, Inc., New York. 1930.

PLUMB, C. S. Judging Farm Animals. Orange Judd Co., New York. 1916.

PLUMB, C. S. Types and Breeds of Farm Animals. Ginn and Co., Boston. 1920.

VAUGHN, H. W. Breeds of Livestock in America. R. G. Adams and Co., Columbus, Ohio. 1931.

YAPP, W. W. AND NEVENS, W. B. "Dairy Cattle Selection," Feeding and Management. Third Edition. John Wiley and Sons, Inc. New York. 1941.

Chapters 21–23

BABCOCK AND CLAUSEN. Genetics in Relation to Agriculture. McGraw-Hill Book Co., New York. 1927.

CASTLE. Genetics and Eugenics. Harvard Univ. Press, Cambridge, Mass. 1930.

CREW. Animal Genetics. Oliver and Boyd, London.

HAGGEDOORN, A. L. Animal Breeding. Second Edition. Crosby Lockwood & Son Ltd. London. 1947.

LUSH, J. L. Animal Breeding Plans. Third Edition. Collegiate Press, Ames, Ia. 1945.

RICE, V. A. Breeding and Improvement of Farm Animals. Third Edition. McGraw-Hill Book Co., New York. 1942.

SINNOT AND DUNN. Principles of Genetics. Third Edition. McGraw-Hill Book Co., New York. 1939.

SNYDER, L. H. Principles of Heredity. D. C. Heath and Co., Boston. 1946.

WHITNEY, L. F. The Basis of Animal Breeding. Earle C. Fowler, Publisher, New Haven, Conn. 1945.

WINTERS, L. M. Animal Breeding. Fourth Edition. John Wiley and Sons, Inc., New York. 1948.

WREIDT, C. W. Heredity in Livestock. The Macmillan Co., New York. 1930.

Chapter 24

DAVENPORT, E. Principles of Breeding. Ginn and Co., Boston. 1907.

FINLAY, G. F. Recent Developments in Cattle Breeding. Oliver and Boyd, London. 1924.

LUSH, J. L. LINEBREEDING. Ia. Agr. Expt. Sta. Bul. 301. 1933.

PRENTICE, E. P. Breeding Profitable Dairy Cattle. Houghton Mifflin Co., Boston. 1935.

SOME RESULTS OF INBREEDING GRADE GUERNSEY AND GRADE HOLSTEIN-FRIESIAN CATTLE. U. S. Dept. Agr. Tech. Bul. 339. 1933.

See also references for Chapters 22 and 23.

Chapter 25

DAWSON, J. R. CARE AND MANAGEMENT OF DAIRY BULLS. U. S. Dept. Agr. Farmers' Bul. 1412.

KILDEE, H. H. AND MCCANDLISH, A. C. INFLUENCE OF ENVIRONMENT AND BREEDING IN INCREASING DAIRY PRODUCTION.—*I*. Ia. Agr. Expt. Sta. Bul. 165. 1916.

MCCANDLISH, A. C., GILLETTE, L. M., AND KILDEE, H. H. INFLUENCE OF ENVIRONMENT AND BREEDING IN INCREASING DAIRY PRODUCTION.—*II*. Ia. Agr. Expt. Sta. Bul. 188. 1919.

MCDOWELL, J. C. DAIRY-HERD IMPROVEMENT THROUGH CO-OPERATIVE BULL ASSOCIATIONS. U. S. Dept. Agr. Farmers' Bul. 1532. 1927.

OLSON, T. M. PUREBRED DAIRY SIRES. S. Dak. Agr. Expt. Sta. Bul. 206. 1930.

WEAVER, E., MATTHEWS, C. A., AND KILDEE, H. H. INFLUENCE OF ENVIRONMENT AND BREEDING IN INCREASING DAIRY PRODUCTION.—*III*. Ia. Agr. Expt. Sta. Bul. 251. 1928.

Chapter 26

ASDELL, S. A. Patterns of Mammalian Reproduction. Comstock Publishing Co., Ithaca, N. Y. 1946.

HAMMOND, JOHN. The Artificial Insemination of Cattle. W. Heffer & Sons Ltd. Cambridge, England. 1947.

HERMAN, H. A. AND MADDEN, F. W. The Artificial Insemination of Dairy Cattle. Lucas Brothers, Columbia, Mo. 1947.

PERRY, E. J. The Artificial Insemination of Farm Animals. Rutgers University Press, New Brunswick, N. J.

Chapter 27

KEENEY, M. H. Cowphilosophy. Second Edition. Holstein-Friesian World, Lacona N. Y. 1944.

PRENTICE, E. P. Breeding Profitable Dairy Cattle. Houghton Mifflin Co., Boston. 1935.

RICE, V. A. Breeding and Improvement of Farm Animals. McGraw-Hill Book Co., New York. 1934.

RUSSELL, J. E. Heredity in Dairy Cattle. American Guernsey Cattle Club. Peterboro, N. H. 1944.

Chapter 28

BRODY, S. Bioenergetics and Growth. Reinhold Publishing Corp., New York. 1945.

HAMMOND, J. The Physiology of Reproduction in the Cow. Cambridge Univ. Press, England. 1927.

JACKSON, C. M. RECENT WORK ON THE EFFECTS OF INANITION AND MALNUTRITION ON GROWTH AND STRUCTURE. Archives of Pathology. Vol. 7, pp. 1042–1078, 1929. Vol. 8, pp. 81–122, 273–315, 1929.

ROBERTSON, T. B. The Chemical Basis of Growth and Senescence. Philadelphia. 1923.

Chapters 29–30

ECKLES, C. H., ANTHONY, E. L., AND PALMER, L. S. Dairy Cattle and Milk Production. The Macmillan Co., New York. 1939.

FRASER, W. J. Dairy Farming. John Wiley and Sons, Inc., New York. 1930.

HENDERSON, H. O., LARSON, C. W., AND PUTNEY, F. S. Dairy Cattle Feeding and Management. John Wiley and Sons, Inc., New York. 1938.

HENDERSON, H. O., BOWLING, G. A., AND HERRMANN, L. F. AMOUNTS OF FEED AND LABOR USED IN RAISING DAIRY HEIFERS. W. Va. Agr. Expt. Sta. Bul. 277. 1936.

MORRISON, F. B. Feeds and Feeding. Twenty-first edition. Morrison Pub. Co., Ithaca, N. Y. 1948.

SAVAGE, E. S., AND CRAWFORD, C. H. DRY CONCENTRATES AS A PARTIAL SUBSTITUTE FOR WHOLE MILK IN CALF RATIONS. Cornell Univ. Agr. Expt. Sta. Bul. 622. 1935.

SLATER, D. J. MARKET CLASSES AND GRADES OF CALVES AND VEALERS. U. S. Dept. Agr. Circ. No. 28. 1928.

YAPP, W. W. AND NEVENS, W. B. Dairy Cattle. Third Edition. John Wiley and Sons, Inc., New York. 1941.

Chapters 31–32

BRESSLAU, E. The Mammary Apparatus of the Mammalian. Methuen and Co., London. 1920.

ESPE, D. Secretion of Milk. Third Edition. Collegiate Press, Inc., Ames, Ia. 1946.

GOWEN, G. W. Milk Secretion. Williams & Wilkins Co., Baltimore. 1930.

PETERSEN, W. E. The Cow's Udder. Bul. 361, Minn. Agr. Expt. Sta. 1942.

TURNER, C. W. Comparative Anatomy of the Mammary Glands. University Co-operative Store, Columbia, Mo. 1939.

Chapter 33

ASSOCIATES OF ROGERS. Fundamentals of Dairy Science. Reinhold Publishing Corp., New York. 1935.

ECKLES, C. H., COMBS, W. B., AND MACY, H. N. Milk and Milk Products. Third Edition. The Macmillan Co., New York. 1943.

ESPE, D. Secretion of Milk. Collegiate Press, Inc., Ames, Ia. 1938.

MAYNARD, L. A. Animal Nutrition. Second edition. McGraw-Hill Book Company, New York. 1947.

MORRISON, F. B. Feeds and Feeding. Twenty-first edition. Morrison Pub. Co., Ithaca, N. Y. 1948.

Chapters 34–37

ECKLES, C. H., ANTHONY, E. L., AND PALMER, L. S. Dairy Cattle and Milk Production. The Macmillan Co., New York. 1939.

FRASER, W. J. Dairy Farming. John Wiley and Sons, Inc., New York. 1930.

HENDERSON, H. O., LARSON, C. M., AND PUTNEY, F. S. Dairy Cattle Feeding and Management. John Wiley and Sons, Inc., New York. 1938.

MORRISON, F. B. Feeds and Feeding. Morrison Pub. Co., Ithaca, N. Y. 1948.

YAPP, W. W. AND NEVENS, W. B. Dairy Cattle Selection, Feeding and Management. John Wiley and Sons, Inc., New York. 1941.

Chapter 38

HAGAN, W. A. The Infectious Diseases of Domestic Animals. Comstock Publishing Co., Inc., Ithaca, New York. 1947.

KEEPING LIVESTOCK HEALTHY. Yearbook of Agriculture. 1942.

LITTLE, R. B. AND PLASTRIDGE, W. N. Bovine Mastitis. McGraw-Hill Book Company, New York. 1946.

Chapter 39

DAIRY BARN CONSTRUCTION. U. S. Dept. Agr., Farmer's Bull. 1942.

DAIRY CATTLE HOUSING IN THE NORTH CENTRAL STATES. Wis. Agr. Expt. Sta. Bul. 47. 1949.

FUNCTIONAL REQUIREMENTS IN DESIGNING DAIRY BARNS. U. S. Dept. Agr. Circ. No. 772. 1945.

VENTILATION OF FARM BARNS. U. S. Dept. Agr. Tech. Bul. 187. 1930.

Chapter 40

WEIR, WILBERT W. Soil Science, Revised. J. B. Lippincott Company, Chicago. 1949.

See *also* Reference Readings for Chapters 33, 34, 35, and 36.

Chapters 41–44

ARMSBY, H. P. The Nutrition of Farm Animals. The Macmillan Co., New York. 1917.

GULLICKSON, T. W. Feeding Dairy Cattle. Webb Book Publishing Co., St. Paul, Minn. 1943.

HENDERSON, H. O., LARSON, C. W., AND PUTNEY, F. S. Dairy Cattle

Feeding and Management. Third edition. John Wiley and Sons, Inc., New York. 1938.

MAYNARD, L. A. Animal Nutrition. Second edition. McGraw-Hill Book Co., New York. 1947.

MORRISON, F. B. Feeds and Feeding. Twenty-first edition. Morrison Pub. Co., Ithaca, N. Y. 1948.

Chapters 45–46

DAVIES, W. L. The Chemistry of Milk. D. Van Nostrand Co., New York. 1936.

ECKLES, C. H., COMBS, W. B., AND MACY, H. N. Milk and Milk Products. Third edition. McGraw-Hill Book Co., New York. 1943.

HUNZIKER, O. F. The Butter Industry. Published by the author, La Grange, Ill. 1940.

RICHMOND, H. D. Dairy Chemistry. C. Griffin and Co., London. 1930.

ROGERS, L. A. AND OTHERS. Fundamentals of Dairy Science. Reinhold Publishing Corp., New York. 1935.

Chapter 47

HAMMER, B. W. Dairy Bacteriology. Third edition. John Wiley and Sons, Inc., New York. 1948.

ORLA-JENSEN, S. Dairy Bacteriology. Second English edition. Blakiston's Co., Philadelphia. 1931.

Standard Methods of Milk Analysis. American Public Health Association, New York. 1948.

Chapter 48

MAJONNIER, AND TROY. The Technical Control of Dairy Products. Majonnier Bros., Chicago. 1922.

METHODS OF ANALYSIS OF MILK AND ITS PRODUCTS. International Association of Milk Dealers, Chicago. 1938.

STANDARD METHODS OF MILK ANALYSIS. American Public Health Association, New York. 1948.

VAN SLYKE, L. C. Modern Methods of Testing Milk and Milk Products. Orange Judd Pub. Co., New York. 1927.

Chapter 49

ECKLES, C. H., COMBS, W. B., AND MACY, H. N. Milk and Milk Products. Third edition. The Macmillan Co., New York. 1943.

HUNZIKER, O. F. Condensed Milk and Milk Powder. Sixth edition. Published by the author, La Grange, Ill. 1946.

JUDKINS, H. F. The Principles of Dairying. John Wiley and Sons, Inc., New York. 1924.

MORTENSEN, M. Management of Dairy Plants. The Macmillan Co., New York. 1938.

ROADHOUSE, C. L. AND HENDERSON, J. L. The Market Milk Industry. McGraw-Hill Book Co., New York. 1941.

SOMMER, H. H. The Theory and Practice of Ice Cream Making. Third edition. Published by the author, Madison, Wis. 1948.

Chapter 50

KELLY, ERNEST AND CLEMENT, C. E. Market Milk. John Wiley and Sons, Inc., New York. 1923.

HARVEY, W. C., AND HILL, H. Milk Production and Control. H. K. Lewis & Co., Ltd., London. 1936.

ROADHOUSE, C. L. AND HENDERSON, J. C. The Market Milk Industry. McGraw-Hill Book Co., New York. 1941.

SOMMER, H. H. Market Milk and Related Products. Published by the author, Madison, Wis. 1938.

Chapter 51

ASSOCIATES OF ROGERS. Fundamentals of Dairy Science. Third edition. Reinhold Publishing Corp., New York. 1936.

GUTHRIE, E. S. Butter. The Macmillan Co., New York. 1918.

HUNZIKER, O. F. The Butter Industry. Third edition. Published by the author, La Grange, Ill. 1940.

TOTMAN, C. C., MCKAY, G. L., AND LARSON, C. Butter. Fourth edition. John Wiley and Sons, Inc., New York. 1945.

Chapter 52

HAMMER, B. W. Dairy Bacteriology. Third edition. John Wiley and Sons, Inc., New York. 1941.

SAMMIS, J. L. Cheese Making. Twelfth edition. The Cheesemaker Book Co., Madison, Wis. 1948.

VAN SLYKE, L. L. AND PRICE, W. V. Cheese. Orange Judd Pub. Co., Inc., New York, 1932.

Chapter 53

HUNZIKER, O. F. Condensed Milk and Milk Powder. Sixth edition. Published by the author, La Grange, Ill. 1946.

SCOTT, A. W. The Engineering Aspects of the Condensing and Drying of Milk. Aird and Coghill, Ltd., Glasgow. 1932.

Chapter 54

DAHLE, C. D. The Manual for Ice Cream Makers. Loyless Pub. Co., Atlanta, Ga. 1927.

SOMMER, H. H. The Theory and Practice of Ice Cream Making. Third edition. Published by the author, Madison, Wis. 1938.

TURNBOW, G. D. AND RAFFETTO, L. A. Ice Cream. John Wiley & Sons, Inc., New York. 1928.

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